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BIOGRAPHICAL MEMOIRS

VOL. XXIII

CITY OF WASHINGTON
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FROM A PHOTOGRAPH TAKEN IN 1876, THE YEAR IN WHICH THE TELEPHONE WAS PATENTED

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BIOGRAPHICAL MEMOIR

OF

ALEXANDER GRAHAM BELL

1847-1922

BY

HAROLD S. OSBORNE

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1943

It was the intention that this Biographical Memoir would be written jointly by the present author and the late Dr. Bancroft Gherardi. The scope of the memoir and plan of work were laid out in cooperation with him, but Dr. Gherardi's untimely death prevented the proposed collaboration in writing the text.

The author expresses his appreciation also of the help of members of the Bell family, particularly Dr. Gilbert Grosvenor, and of Mr. R. T. Barrett and Mr. A. M. Dowling of the American Telephone & Telegraph Company staff. The courtesy of these gentlemen has included, in addition to other help, making available to the author historic documents relating to the life of Alexander Graham Bell in the files of the National Geographic Society and in the Historical Museum of the American Telephone and Telegraph Company.

ALEXANDER GRAHAM BELL

1847–1922

BY HAROLD S. OSBORNE

Alexander Graham Bell—teacher, scientist, inventor, gentleman—was one whose life was devoted to the benefit of mankind with unusual success. Known throughout the world as the inventor of the telephone, he made also other inventions and scientific discoveries of first importance, greatly advanced the methods and practices for teaching the deaf and came to be admired and loved throughout the world for his accuracy of thought and expression, his rigid code of honor, punctilious courtesy, and unfailing generosity in helping others.

The invention of the telephone by Alexander Graham Bell was not an accident. It came as a logical result of years of intense application to the problem, guided by an intimate knowledge of speech obtained through his devotion to the problem of teaching the deaf to talk and backed by two generations of distinguished activity in the field of speech.

Bell's grandfather, Alexander Bell (born at St. Andrews, Scotland, 1790, died at London, 1865) achieved distinction for his treatment of impediments of speech, also as a teacher of diction and author of books on the principles of correct speech and as a public reader of Shakespeare's plays. Young Alexander Graham Bell, at the age of 13, spent a year in London with his grandfather. He was already interested in speech through his father's prominence in this field, and this visit stimulated him to serious studies. Bell afterwards spoke of this year as the turning point of his life.

Bell's father, Alexander Melville Bell (born in Edinburgh, Scotland, 1819, died at Washington, 1905), was for a time professional assistant to Alexander Bell, then he became lecturer on elocution in the University of Edinburgh. He developed "Visible Speech," a series of symbols indicating the anatomical positions which the speaking organs take in uttering different sounds. This won him great distinction and, with improvements made by Alexander Graham Bell, is still a basis for teaching the deaf to talk. On the death of his father in 1865, Melville Bell

moved to London, to take over his professional practice. He also became lecturer on elocution at University College and achieved distinction as a scientist, author and lecturer on both sides of the Atlantic.

In 1844 he married Miss Eliza Grace Symonds, daughter of a surgeon of the Royal Navy, a talented musician.

Alexander Graham Bell, the second of three sons of Melville Bell, was born March 3, 1847, in Edinburgh. From his mother, he inherited musical talent and a keen musical ear. He took lessons on the piano at an early age and for some time intended to become a professional musician.

His father's devotion to the scientific study of speech had an early impact on the boy. "From my earliest childhood," said Alexander Graham Bell, "my attention was specially directed to the subject of acoustics, and specially to the subject of speech, and I was urged by my father to study everything relating to these subjects, as they would have an important bearing upon what was to be my professional work. He also encouraged me to experiment, and offered a prize to his sons for the successful construction of a speaking machine. I made a machine of this kind, as a boy, and was able to make it articulate a few words." This early illustrates his energy, his ambition, and his inventive ingenuity.

Always an individualist, Bell decided at the age of 16 to break away from home and teach. His first position was pupil-teacher in Weston House Academy, a boys' school at Elgin, Scotland. After a year here he returned to the University of Edinburgh for a course in classical studies and then returned to the Academy a year later as teacher of elocution and music. His scientific curiosity, a prominent characteristic throughout his life, is illustrated by his studies, made at this early age, of the resonance pitches of vowels. Placing his mouth in position for the utterance of various vowel sounds, he was able to develop two distinct resonance pitches for each vowel, tapping with a finger a pencil placed on the throat or on the cheek. The young man transmitted a lengthy account of his researches to his father and through him to Alexander John Ellis, President of the London Philological Society. Through Ellis, Bell learned that

similar experiments had long before been made by Helmholtz with the aid of electromagnetically controlled tuning forks. Unable to repeat Helmholtz' experiments at the time because of insufficient electrical knowledge, he determined to study electricity, including its principal application, telegraphy, for he felt it was his duty as a student of speech to study Helmholtz' researches and repeat his experiments.

In 1868, Alexander Graham Bell took over his father's professional engagements in London while Melville Bell gave lectures in America. Entering into the opportunities of this life in London with characteristic energy and enthusiasm, he was launched on a career of feverish activity with a heavy program of teaching, lecturing, studying and experimenting.

At about this time, tragedy struck the Bell household. In 1867, Bell's younger brother had died of tuberculosis. In 1870 his older brother died of the same cause. The health of Alexander Graham Bell himself became seriously impaired under the strain of his active career. Melville Bell acted swiftly to save his only remaining son. He gave up his professional career in London and in the summer of 1870 moved to the "bracing climate" of America. He settled in Brantford, Ontario, for what was intended to be a two-year trial period.

In the new environment, Alexander Graham Bell's health rapidly improved, so much so that in 1871 his father suggested that he be invited to Boston to fill a request for lectures on visible speech to teachers of the deaf. The invitation was given and accepted.

The success of these lectures, which began in April, 1871, led to a succession of engagements and to the rapid establishment of Bell in Boston as a leader in the field of teaching the deaf to speak. Shortly after taking up this work, Bell was entrusted with the entire education of Mr. Thomas Sanders' five-year-old son George, who was born deaf, and a year or two later, Mr. Gardiner G. Hubbard of Boston brought to Bell his sixteen-year-old daughter, Mabel, deaf since early childhood, for instruction in speech. These associations were destined to have a profound influence on Bell's life.

While in Brantford (August, 1870-March 1871) and later in Boston, Alexander Graham Bell continued his studies of Helmholtz' electrical experiments. Working with electrical circuits controlled by tuning forks led Bell to consider the invention of the harmonic telegraph, that is, a telegraph system making possible a number of simultaneous transmissions over the same wire by the use of different frequencies of interruption of the electric current. The idea was not novel with him, for the harmonic telegraph had for some time lured inventors with the promise of rich reward. Bell believed that his experiments gave him the clue to important improvements in this system and by 1873 he was working hard on this invention.

At that time all experiments on the harmonic telegraph were made with interrupted electrical current, e.g., with circuits in which electrical impulses were produced by alternately opening and closing the circuit. The interrupted current, acting upon a mechanically resonant receiving device, such as a reed, properly tuned, would cause it to vibrate. When the effort was made, however, to achieve harmonic telegraphy by operating simultaneously over the same circuit a number of devices of this sort using different frequencies, inventors, including Bell, found great and unexpected difficulties.

During this period, Bell's intense experimental activities were by no means confined to the harmonic telegraph. His profession was teaching the deaf to speak. His imagination was fired with the idea that if deaf children could "see" speech as it is spoken they might be taught more easily to articulate. With this in mind he worked with the manometric capsule of Koenig, a device which produces a band of light with an outline pattern corresponding to the sound pattern spoken into it; and with the phonautograph, which scratches a pattern on smoked glass conforming with the pattern of the sound spoken before it. His idea was to prepare standard patterns of the various sounds with the phonautograph and have the deaf children enunciate into the manometric capsule until they could produce light patterns identical with the standards. He built a number of phonautographs of his own. For one he used an actual human ear provided by Dr. Clarence J. Blake, a distinguished aurist

of Boston whom he had consulted in the matter. While these experiments failed in their direct aim they later were given credit by Bell for suggesting to his mind the great conception of a speaking telephone with a single vibrating membrane.

Other inventors had worked on the problem of transmitting speech electrically but had found no way to do it. Bourseul in 1854, had proposed it, but offered no solution of the problem. About 1861 Philip Reis (in Germany) had produced a device in which, by very rapid interruptions of the current in a circuit, an iron rod surrounded by a coil of wire at the receiving end was made to vibrate and thus a musical tone was produced. Reis called his device a telephone. It was, of course, not a telephone in the present sense of the word, as the interrupted current was far too crude a medium for the transmission of speech.

By the summer of 1874, Bell had achieved the conception that "It would be possible to transmit sounds of any sort if we could only occasion a variation in the intensity of your current exactly like that occurring in the density of the air while a given sound is made." It also occurred to Bell that this variation of the current could be caused by the movement of a single steel reed in a magnetic field if some way could be found to move it in the same way as the air is moved by the action of the voice. Speaking later of his phonautograph constructed from the human ear, he said, "I was much struck by the disproportion in weight between the membrane and the bones that were moved by it; and it occurred to me that if such a thin and delicate membrane could move bones that were, relatively to it, very massive indeed, why should not a larger and stouter membrane be able to move a piece of steel in the manner I desired? At once the conception of a membrane speaking telephone became complete in my mind." At the moment, however, Bell did not know how to reduce this conception to practice. While he knew that the motion of iron in a magnetic field would produce magneto-electric currents, he had the idea that "magneto-electric currents, generated by the action of the voice alone" would be too feeble to produce audible effects from a receiving telephone.

In this critical time in Bell's thinking about his great invention occurred the famous meeting between Bell and Joseph Henry. On March 2, 1875, Bell had occasion to visit Washington in connection with his harmonic telegraph patents. Bell had a letter of introduction to Professor Henry, who was then nearly 80, Secretary of the Smithsonian Institution and dean of American scientists. Bell described his experiments on the harmonic telegraph to an attentive ear. One experiment so aroused Henry's interest that Bell brought his apparatus to the Institution the next day and Henry spent much time experimenting with it. A few days later, Bell wrote to his parents, "I felt so much encouraged by his interest that I determined to ask his advice about the apparatus I have designed for the transmission of the human voice by telegraph. I explained the idea and said, 'What would you advise me to do—Publish it and let others work it out—or attempt to solve the problem myself?'

"He said he thought it was 'the germ of a great invention'—and advised me to work at it myself instead of publishing.

"I said that I recognized the fact that there were mechanical difficulties in the way that rendered the plan impracticable at the present time. I added that I felt that I had not the electrical knowledge necessary to overcome the difficulties. His laconic answer was—'*Get it.*'

"I cannot tell you how much these two words have encouraged me. . . . Such a chimerical idea as telegraphing *vocal sounds* would indeed to most minds seem scarcely feasible enough to spend time in working over.

"I believe, however, that it is feasible, and that I have got the cue to the solution of the problem."

In spite of this encouragement, for several months the idea of the telephone was pushed into the back of Bell's mind. During the hours that could be snatched from his professional work he was working on his invention of the harmonic telegraph which his financial backers, Gardiner G. Hubbard and Thomas Sanders, were anxious to have completed at the earliest possible date. On June 2, while he was engaged in this work with his assistant. Thomas A. Watson, one of the transmitting reeds became out of adjustment so that when plucked it did

not interrupt the circuit but merely vibrated before its associated electromagnet without opening the contacts. Bell's musical ear and trained observation caused him to note at once the different quality of the sound produced by the vibration of the corresponding reed at the receiving end. He immediately investigated the cause of this change. He was surprised and delighted to find that without interruption of the circuit the inductive effect of the vibrating reed at the sending end produced enough current to cause the receiving end to vibrate audibly. "These experiments," he said, "at once removed the doubt that had been in my mind since the summer of 1874, that magneto-electric currents generated by the vibration of an armature in front of an electro-magnet would be too feeble to produce audible effects . . ." Immediately he felt that he had the key to the fulfillment of his long cherished dream of the electrical speaking telephone. Before the night was over he had made sketches for the first models and asked Watson to build them without delay.

The following months were difficult for Bell. His inventive interest was centered on his hopes for realizing the electrical transmission of speech, hopes which were aroused to a high pitch. But his time was fully committed elsewhere. Hubbard and Sanders had financially backed his invention of the harmonic telegraph, and he felt obligated to press forward with that project. Nevertheless he found time, by great exertion and excessively long hours, to work on his new idea. The first models did not prove satisfactory and successive modifications were made. At last, early in July, while Bell and Watson were testing a new pair of models, Watson rushed upstairs in great excitement to tell Bell that "He could hear my voice quite plainly, and could almost make out what I said." This was enough to convince Bell that he was on the right track.

The pressure of this program proved too much for Bell's health, and in August he was obliged to return to his father's home in Brantford to recuperate. While there he began writing his patent specifications covering his conception of the undulatory current. Here also he continued his telegraph experiments, especially on means of quenching sparks at contacts. For this

purpose he devised a variable water resistance to bridge the contact points. It was this work that suggested the first form of variable resistance transmitter, later used when the first complete sentence was transmitted electrically.

On his return to Boston, Bell's time was largely taken up with the organization and conduct of a normal class for the instruction of teachers of the deaf and with lectures at the Boston University. Now engaged to Hubbard's daughter, he was reluctant to call on his backers for further financial assistance and felt that he should insure adequate support from his teaching before resuming his electrical experiments. He wrote Mabel Hubbard at this period that he would be glad when his plans for the normal class were completed, "for my mind will then be free to bend all its energies upon telegraphy." With his normal class well under way, Bell's time was taken up with the completion of his telephone patent applications and visits to his attorneys in Washington. After his patent was allowed, March 3, 1876 (issued on March 7, 1876), Bell returned to Boston and a few days later, March 10, 1876, transmitted the first sentence ever sent over wires electrically, using the liquid transmitter suggested by his telegraph experiments.

The fertility of Bell's genius is illustrated by the breadth and scope of the first two patents relating to the telephone. They cover the broad conception of the undulatory rather than the interrupted current as applied both to harmonic telegraphy and to the speaking telephone. They cover the production of the undulatory current both by magnetic induction (vibrating iron before a magnet on which a coil of wire has been placed) and by varying a resistance (as is done in the modern transmitter). They cover telephones with a non-magnetic diaphragm to which a piece of iron has been attached, as in Bell's original models, and with iron or steel diaphragms which Bell quickly found to be more effective.

In 1883 a journalist wrote, "The issuance of Bell's patent on March 7, 1876, attracted little or no attention in the telegraphic world. The inventor was practically unknown in electrical circles, and his invention was looked upon, if indeed any notice at all was taken of it, as utterly valueless."

A lively interest in Bell's invention, however, quickly arose in scientific circles. It was stimulated by the successful demonstration of the telephone at the International Centennial Exposition at Philadelphia, to a committee of judges including Sir William Thomson, Joseph Henry and other prominent scientific men. As a result of this demonstration on June 25, 1876, Bell was given a Certificate of Award. Sir William Thomson wrote later of the telephone, "This, the greatest by far of all the marvels of the electric telegraph, is due to a young countryman of our own, Mr. Graham Bell, of Edinburgh and Montreal and Boston, now becoming a naturalized citizen of the United States. Who can but admire the hardihood of invention which has devised such very slight means to realize the mathematical conception that, if electricity is to convey all the delicacies of quality which distinguish articulate speech, the strength of its current must vary continuously and as nearly as may be in simple proportion to the velocity of a particle of air engaged in constituting the sound."

The telephone was described and demonstrated before the American Academy of Arts and Sciences in Boston on May 10, 1876. Demonstrations followed in rapid succession in Boston later on in May, at Brantford in August, between Boston and Cambridge in November. On November 26, Bell talked from Boston with Watson who was in Salem 16 miles away, "the greatest success yet achieved," Bell wrote Mabel Hubbard. On December 3, there was a similar demonstration between Boston and North Conway, New Hampshire, a distance of 143 miles. Other demonstrations and lectures followed.

After the issuance of his second telephone patent, in January, 1877, Bell spent a few months on lectures, demonstrations and experiments. He married Mabel Hubbard July 11 and with her left in August for an extended trip to England to interest English capital in the new invention. On March 5, 1878, he wrote a letter outlining for the British capitalists his ideas of the future usefulness of his scientific toy. To quote merely a single paragraph of this remarkable document:

". . . it is conceivable that cables of Telephonic wires could be laid under-ground or suspended overhead communicating by

branch wires with private dwellings, counting houses, shops, manufactories, etc., etc., uniting them through the main cable with a central office where the wires could be connected together as desired, establishing direct communication between any two places in the City. Such a plan as this though impracticable at the present moment will, I firmly believe, be the outcome of the introduction of the Telephone to the public. Not only so but I believe that in the future wires will unite the head offices of Telephone Companies in different cities and a man in one part of the Country may communicate by word of mouth with another in a distant place."

By the middle of 1877, the telephone was put into commercial use in this country under the skillful direction of Mr. Gardiner G. Hubbard. Its immediate commercial success led to a flood of litigation over the Bell patents which lasted throughout their life. A part of this arose from mere fraud, inspired by the great value of the invention. Much of it centered about the fact that other competent men had been interested in this great problem, and had come near to solving it. But the end result of all this welter of litigation was that Bell was upheld as the inventor of the telephone because he was the first to conceive and apply the crucial idea of the undulatory current, in contrast to the older art of interrupted current. As stated in the controlling court decision, an opinion of the Supreme Court of the United States delivered by Chief Justice Waite: "It had long been believed that, if the vibrations of air caused by the voice in speaking could be reproduced at a distance by means of electricity, the speech itself would be reproduced and understood. How to do it was the question. Bell discovered that it could be done by gradually changing the intensity of a continuous electric current, so as to make it correspond exactly to the changes in the density of the air caused by the sound of the voice. This was his art. He then devised a way in which these changes of intensity could be made and speech actually transmitted. Thus his art was put into condition for practical use."

On his return to America in November, 1878, Bell was obliged to give a great deal of time to testifying in these patent suits in defense of his inventions. A man of scrupulous honesty, careful to avoid credit for anything which was not his due, Bell

naturally found it distasteful in the highest degree to be subjected on the witness stand to repeated charges of fraud and misrepresentation. He recognized the importance of these suits, however, and fully carried out his obligation to defend his patents. His masterly testimony in the numerous cases was of greatest importance in bringing about the successful outcome.

In addition to testifying in the numerous patent suits, Bell also, acting in a consulting capacity for the telephone companies, made various suggestions for the development of the telephone system and called attention to any developments which he thought might profitably be applied. He wrote in May, 1880, of his success in transmitting sound to a maximum distance of 800 feet using a beam of light and a selenium cell. He asked the company to take out a patent immediately. "If not, I wish to be permitted to publish an account of this discovery at once in some of the leading scientific periodicals."

His interests, however, were much broader than telephony, and the breadth of these interests led him to turn his attention into other fields as rapidly as his obligations to the developers of the telephone made this possible. As leisure and wealth came to him from his telephone invention, it became possible for him to devote his time to researches in numerous subjects which interested him and which gave opportunity for further service to mankind.

Running through all of Bell's adult life is his interest in improving the teaching of the deaf. This began even before he left London, and in this country as early as 1871 he accepted engagements in Boston to explain the application of his father's system of visible speech to teaching the deaf and dumb to talk. At that time, deaf children were generally taught to speak among themselves by sign language. Many leading authorities considered that it was impracticable and a waste of time to try to teach speech to the deaf and dumb—it was even commonly supposed that their organs of speech had been impaired. At one time Bell, as well as his father, had held, as he expressed it, "an obstinate disbelief in the powers of lip reading." Later he became convinced of these powers, partly perhaps through the ease

with which he could converse with Mabel Hubbard, who had become adept at lip-reading.

Characteristically, when Bell recognized his misconception he was quick to correct it in an active way. As early as 1872 he began a crusade for recognizing the intellectual possibilities of deaf children and for teaching them to speak and read lips rather than being content to teach them sign language. His influence spread rapidly, helped by the success of his application of visible speech to teaching the deaf to talk. On January 24, 1874, he addressed the first convention of Articulation Teachers of the Deaf and Dumb and he continued to take an active part in this and other organizations of a similar nature. While this work was interrupted in the years 1875 to 1878 by his activities on the telephone and associated inventions, he threw himself into the work again on his return to America in 1878.

In 1880, he received the Volta Award of 50,000 francs for his invention of the telephone. With this he founded the Volta Laboratory Association (later the Volta Bureau), which was largely devoted to work for the deaf. In 1883, after an exhaustive study, he presented before the National Academy of Sciences a memoir: "Upon the formation of a deaf variety of the human race." In this he traced the eugenic dangers of the enforced segregation of deaf people which resulted from teaching them sign language rather than teaching them to speak and read lips. In 1884, he made a plea before the National Education Association for the opening of day schools for the deaf as one means of reducing this danger.

There were tendencies for the proponents of sign language and of articulation to break into two hostile camps. However, Bell's conciliatory policy held the group together and led in 1890 to the organization of the American Association to Promote the Teaching of Speech to the Deaf. Bell was President of this organization and heavily supported its work, giving a total of more than $300,000.

In 1888, at the invitation of the Royal Commission appointed by the British government to study the condition of the deaf, Bell gave exhaustive testimony before them based upon his experience and upon an extensive study of conditions in Amer-

ica. He was appointed an expert special agent of the Census Bureau to arrange for obtaining adequate data regarding the deaf in the census of 1900 in this country and devoted large amounts of time to this work at great personal sacrifice. It is not surprising that at the World's Congress of Instructors of the Deaf held in Chicago in 1893, Dr. Bell was held as the man to whom "*more than any other man* not directly connected with the work, we are indebted for the great advance made in teaching speech to the deaf, and in the establishment of oral schools of instruction throughout the country."

Among the honors received by Dr. Bell, some of those which touched him the most were the naming for him of several schools for the deaf. Among his many honorary degrees, Harvard College in 1896 gave him LL.D. for his scientific achievements and work for the deaf child.

Bell's work on the eugenic dangers of the enforced segregation of deaf people led him into pioneer work in the general field of eugenics which, throughout his life, continued to be one of his important interests. In 1918 and 1919 he published the results of extensive studies of longevity and of the betterment of the human race by heredity. In 1921 he was made Honorary President of the Second International Congress of Eugenics at New York City. During the last 30 years of his life he carried on continuously breeding experiments with sheep, leading towards the development of a more prolific breed. These experiments are still going on with the original line in Middlebury, Vermont, with encouraging results.

In spite of all these accomplishments, Bell's incessant activity gave him time to apply his genius with profit to other fields. One of the most important of Bell's inventions outside of the telephone field resulted directly from the Volta prize. Bell's interest in speech led to the development by the Volta Laboratory of the engraving of wax for phonograph records, applicable to both the cylindrical and flat disk forms. A fundamental patent was obtained on this now generally used type of record. It is of interest to note that one of the original records developed by Bell and his associates, which was deposited at the Smithsonian Institution in 1881 in a sealed package, with in-

structions that it should be opened in 50 years, was recently played in the presence of Mr. Bell's daughters and of interested scientists.

Another invention of importance was the telephone probe, an adaptation of the telephone and the electric circuit, to determine the location of a bullet or metallic masses in the human body. In recognition of this, and other inventions, the University of Heidelberg gave him the honorary degree of M. D. in 1886.

Nothing better illustrates Bell's independence of thought than his staunch support of aviation at a time when it was considered so quixotic a subject that Bell risked his scientific reputation in so doing. As Lord Kelvin wrote to Mrs. Bell in 1898, "When I spoke to him on the subject at Halifax, I wished to dissuade him from giving his valuable time and resources to attempts which I believed, and still believe, could only lead to disappointment, if carried on with any expectation of leading to a useful flying machine."

In 1891 Bell contributed $5,000 for Langley's aviation experiments. On May 6, 1896, he saw the successful flight of Langley's steam-driven 16 foot model, which, however, did not carry a man. Speaking of this experience later, he said, "The sight of Langley's steam aerodrome circling in the sky convinced me that the age of the flying machine was at hand."

In 1898, Bell was elected a Regent of the Smithsonian Institution. His enthusiasm for Langley's experiments with small-scale models of a flying machine had much to do with obtaining from the War Department an appropriation of $50,000 to be used by Langley for the development of aeronautics.

Langley's full scale model, carrying a pilot, fell into the Potomac on its trial in 1903, and the whole project dissolved in ridicule. However, soon after this the Wright brothers made their epochal flight at Kitty-Hawk, the first man-carrying flight of a controlled airplane. These events further confirmed the abiding interest in aviation of Alexander Graham Bell.

For years Bell had been studying the flight of kites at his summer home, Beinn Bhreagh, in Cape Breton Island on the Bras D'Or. This he considered the best approach to the prob-

lem of aviation. By 1901 he was working with a tetrahedral form of kite structure, a form which gave stability. This work was greatly expanded in the following years. Giant kites of multicellular, tetrahedral form were built and flown. In 1907 his huge kite Cygnet I, towed across Baddeck Bay carrying Lieutenant Selfridge, rose to a height of 168 feet.

While Bell's tremendous experimentation in this field was without direct application to aeronautics, indirectly it was of importance. It led Mr. and Mrs. Bell to become patrons of aeronautical research and greatly to advance aviation in this way. In connection with his experimental work, Bell attracted to his home at Beinn Bhreagh a group of talented young men devoted to aviation. In October, 1907, he entered into an agreement with these men for their joint production of experiments on "aerial locomotion," "all working together individually and conjointly in pursuance of their common aim to get into the air by the construction of a practical aerodrome driven by its own motive power and carrying a man." This organization was named the Aerial Experiment Association, and its work was financed by Mrs. Bell. The Association included Bell, Glenn H. Curtis, F. W. Baldwin, J. A. D. McCurdy, and Lieut. T. Selfridge. Bell was chairman.

The Aerial Experiment Association, during its one and one-half years of activity, principally at Hammondsport, N. Y., made important contributions to the development of aviation. In March 1908, their first machine, piloted by "Casey" Baldwin, made an important public flight, rising 10 feet above Lake Keuka for a distance of over 300 feet. One of the achievements of this flight was a demonstration of the aileron as an improvement over the wing-warping method previously used by the Wrights for obtaining stability. The aileron is fundamental to all airplane construction today. The second machine of the Association introduced the doped fabric which played so important a part as a wing cover through 20 years of the development of flying. The third machine, designed by Curtis, flew so well that it was entered for the *Scientific American* trophy for the first public flight of one kilometer, straightaway. The flight was made July 4, 1908, and the trophy won. The fourth

machine of the Association used balloon fabric for the wings and proved very successful. In the winter of 1909, McCurdy made repeated flights at Beinn Bhreagh, sometimes doing nine miles at a stretch. The Association was dissolved at midnight March 31, 1909, with a resolution by the members "that we place on record our high appreciation of her (Mrs. Bell's) loving and sympathetic devotion without which the work of the Association would have come to naught."

As in the case of his work on the telephone, Bell's activity for the advancement of aviation was stimulated by a prophetic vision of the future importance of developments in this field. In 1908, asked by the editor of *Century* to comment on proofs of an article by E. C. Stedman entitled "The Prince of the Power of the Air," Bell wrote: "While, of course, the bird is Nature's model for the flying-machine heavier than air, Mr. Stedman is undoubtedly right in looking upon the fish as the true model for the dirigible balloon. It is certainly noteworthy that the dirigible war-balloon of today already approximates the fish-like form predicted by him. He is also right I think in supposing that of all the nations in the world the interests of Great Britain will be most vitally affected by progress in aeronautics. For it is obvious that sea-power will become of secondary importance when air-power has been fully developed through the use of dirigible balloons and flying machines in war. The nation that secures control of the air will ultimately rule the world."

This brief description of some of Bell's chief accomplishments gives also an indication of some of his outstanding personal characteristics. He was one of driving energy, insatiable scientific curiosity, independence of thought and individuality of action. As a young man, he was tall, dark with flashing eyes, somewhat frail in appearance. He was described by an observer in 1877 as follows: "Professor Bell is a man of most genial and kindly presence, so courteous and gracious in manner that you could not feel yourself an intruder though you chanced to drop into his room when some private class was under special training. At the same time though his affability sets you at ease, you could not fail to observe that he is one of the busiest

of men, so intent upon the development of plans which occupy his life that he has no leisure for visitors who are not interested in his work. He is young, apparently not more than five and thirty (he was just 30) with an unusually prepossessing countenance; very happy in his expression; of pale complexion with jet black hair brushed up from his forehead and pleasant, sparkling black eyes—the face of a man all engaged in his work and finding satisfaction in it."

Later in life, Bell's health became more stable, his frame filled out, his hair became white and his whole appearance impressive and commanding.

Bell's code of honor included scrupulous regard for the exact description of his own contributions to inventions or researches and credit to those of others. He was present at the Second Annual Banquet of the Aerial Club of America shortly after the successful flight of the first machine of the Aerial Experiment Association. Cheered to his feet by prolonged applause of this performance, he said, "I really had nothing to do with the success of the experiment. The credit for its success was due to Mr. G. H. Curtis, Mr. F. W. Baldwin and Mr. J. A. D. McCurdy. . . . In this company of experimenters I must include Lieutenant Selfridge of the United States Army and Mrs. Bell who supplied the capital for the scientific experiments to get the machine into the air."

His appreciation of assistance and encouragement received from others was warmly felt and often expressed in some tangible and suitable way. Though Henry died before the telephone was well established, Bell saw to it that an instrument was installed without charge in Henry's residence for the use of his family, "in recognition," Bell said, "of the efforts and services of Prof. Henry in the early history of the instrument and who did a great deal to encourage the inventor."

Bell's services to the promotion of science extended far beyond his own researches. From 1898 to 1903, he was President of the National Geographic Society and did much to develop the policy of that Society and of its magazine in the channels which have led to the present tremendous membership and influence. He served as Regent of the Smithsonian Institution from 1898

until his death. In 1890, a generous gift by him helped start the Astrophysical Observatory of the Institution and in 1894 he brought the body of James Smithson, founder of the Smithsonian Institution, from Genoa to Washington.

Honors came to Bell in great number. Some of these have been mentioned in the discussion of his achievements. He received a large number of honorary degrees from universities in America, in the British Isles and in Germany. He was elected a member of the National Academy of Sciences in 1883. He was made an Officer of the Legion of Honor of France in 1881. He was awarded a medal by the Louisiana Purchase Exposition in 1904, the John Fritz Medal from a group of national engineering societies in 1907, the Elliott Cresson Medal from the Franklin Institute in 1912, the David Edward Hughes Medal from the Royal Society, London, in 1913; the Thomas Alva Edison Medal by the American Institute of Electrical Engineers in 1914, and the Civic Forum (New York) Medal in 1917. In 1917 the Governor General of Canada unveiled a Bell Telephone Memorial erected in his honor at Brantford, Ontario, in the Alexander Graham Bell Gardens and dedicated the Bell homestead and grounds as part of the public parks system of Brantford. In 1920, his native city of Edinburgh elected him a Burgess and a Guild Brother of the city and conferred upon him "The freedom of the city of Edinburgh in recognition of his great achievement in the solution of the problem of telephone communication and of his brilliant and distinguished career as a scientist." This was an honor which deeply touched his heart.

Early in his professional work Bell determined to become a citizen of the United States, taking out his first papers in 1874 and receiving his final papers in 1882. He was immensely proud of his American citizenship, which, as he stated, was his by choice rather than by accident.

In the later years of his life, Bell spent more and more time at his summer estate, Beinn Bhreagh, in Nova Scotia. Here, on August 2, 1922, he died. Here he was buried on the top of a mountain in a tomb cut out of a solid rock, with the epitaph, "Died a citizen of the U. S. A." During the ceremony, every telephone on the continent of North America was silenced in

honor of the man who had given to mankind the means for direct communication at a distance.

Not only did Alexander Graham Bell leave the telephone as a perpetual memorial to him but the influence of his personality remains strong on those who knew and loved him. Even now, 20 years later, a scientist who for many years knew him well, writes, "The fact that he never spoke disparagingly of others was a remarkable trait, the value of which nowadays I appreciate more than I did when he was alive. I miss his personality more than that of any other human being who has come and gone in my life."

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Patent No.	*Date of Issue*	*Title of Invention*
161,739	Apr. 6, 1875	Improvement in Transmitters and Receivers for Electric-Telegraphs
174,465[1]	Mar. 7, 1876	Improvement in Telegraphy
178,399	June 6, 1876	Telephonic Telegraph-Receivers
181,553	Aug. 29, 1876	Improvement in Generating Electric Currents
186,787[1]	Jan. 30, 1877	Improvement in Electric Telegraphy

[1] The basic telephone patents, known as "The Bell Patents."

Patent No.	*Date of Issue*	*Title of Invention*
201,488	Mar. 19, 1878	Improvement in Speaking-Telephones
213,090	Mar. 11, 1879	Improvement in Electric Speaking-Telephones
220,791	Oct. 21, 1879	Improvement in Telephone-Circuits
228,507	June 8, 1880	Electric Telephone-Transmitter
230,168	July 20, 1880	Automatic Short-Circuiter for Telephones
235,199	Dec. 7, 1880	Apparatus for Signaling and Communicating, Called "Photophone"
*235,496	Dec. 14, 1880	Photophone-Transmitter
*235,497	Dec. 14, 1880	Selenium-Cell
*235,616	Dec. 21, 1880	Process of Treating Selenium to Increase its Electric Conductivity
238,833	Mar. 15, 1881	Electric Call-Bell
241,184	May 10, 1881	Telephonic Receiver
*241,909	May 24, 1881	Photophonic Receiver
244,426	July 19, 1881	Telephone-Circuit
250,704	Dec. 13, 1881	Speaking-Telephone
**341,212	May 4, 1886	Reproducing Sounds from Phonograph Records
**341,213	May 4, 1886	Transmitting and Recording Sounds by Radiant Energy
757,012	Apr. 12, 1904	Aerial Vehicle
770,626	Sep. 20, 1904	Aerial Vehicle or Other Structure
†856,838	June 11, 1907	Connecting Device for the Frames of Aerial Vehicles and Other Structures
††1,011,106	Dec. 5, 1911	Flying-Machine
1,050,601	Jan. 14, 1913	Flying-Machine
‡1,410,874	Mar. 28, 1922	Hydrodrome, Hydroaeroplane, and the Like
‡1,410,875	Mar. 28, 1922	Hydrodrome, Hydroaeroplane, and the Like
‡1,410,876	Mar. 28, 1922	Hydrodrome, Hydroaeroplane, and the Like
‡‡1,410,877	Mar. 28, 1922	Hydrodrome, Hydroaeroplane, and the Like

* Issued to A. G. Bell and Sumner Tainter
** Issued to A. G. Bell, Chichester A. Bell and Sumner Tainter
† Issued to A. G. Bell and Hector P. McNeil
†† Issued to A. G. Bell, Frederick W. Baldwin, John A. Douglas McCurdy, Glenn H. Curtis and Edward A. Selfridge, Deceased, Assignors to Charles J. Bell, Trustee.
‡ Issued to A. G. Bell and Frederick W. Baldwin
‡‡ Issued to A. G. Bell, Frederick W. Baldwin and Sydney S. Breese

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1878–1942

BY WALTER B. CANNON

Wide-ranging erudition was a prominent feature of Lawrence Henderson's qualities. His intellectual interests and his learning were remarkedly diverse and impressive. Biochemistry, general physiology, oceanography, philosophy, history of science, human problems of industry, sociological theory—all these subjects and others related to them enthralled him at one time or another during his adult career. Besides these varied appreciations and understandings he possessed a highly creative imagination, manifest by noteworthy achievements in scientific discoveries and in university organization. And through his influence on superior students he left deep and lasting memories of friendly personal concern and of generous sharing of fruitful ideas.

L. J. Henderson was born in Lynn, Massachusetts, June 3, 1878. His father, Joseph Henderson, a business man, seems not to have greatly influenced his life. His mother was a woman of unusual character. Reared in a pioneer settlement of Ohio, she showed, under primitive conditions, much adaptability and good sense. Her father, whom she revered, was "the most democratic person she ever knew"; as evidence, discussing politics, theology, law, philosophy and other topics with equal zest with the only very wealthy man of the region and with a well-informed Scotchman who broke stones for road building. Mrs. Henderson, though disciplined as a child in strict Calvinism, clearly developed independent judgment, for she wrote late in her life, "Theology is a thing which in the last 2000 years has caused more misery and suffering—woe of body and mind—in the world than almost anything else, unless perhaps the inordinate pursuit of riches and power. I have hated creeds since I was a child." Mrs. Henderson's brother, Milton, was a "mathematician of exceptional ability and eager for knowledge," according to her testimony.

Lawrence, small and feeble as an infant, later participated in school athletics and had the reputation of being a swift runner.

During his early education he found mathematics peculiarly easy and he developed a special fondness for physics. He entered Harvard College at the early age of 16, in 1894. The freedom of thought and action which prevailed provided him with a highly congenial atmosphere. He went his way independently, listening to his instructors, but responding to their teaching as seemed to him best. An early and a central attraction was chemistry. By his second year he had decided to study seriously biological chemistry, though no courses in the subject were offered in the College. Physical chemistry as a preparation for later uses led him to thinking about solutions and the establishment of equilibria between acids and bases—a concern which years afterwards had important consequences in his description of conditions in blood. As indicating his collegiate interest in physical chemistry an essay may be mentioned which he submitted for a Bowdoin Prize, on Arrhenius's theory of electrolytic dissociation.

Henderson received the A. B. degree, *magna cum laude,* in 1898, and that autumn entered the Harvard Medical School. It is noteworthy that then the College offered no adequate instruction in physiology or biochemistry and that "physiological chemistry," even in the Medical School, was concerned mainly with training in examination of body fluids and excreta. The medical curriculum did present, however, opportunity for acquaintance with one organism, the human body, and its disorders, an opportunity unmatched elsewhere in the University. Again he went his own way, independently, living in Cambridge, maintaining collegiate friendships and associations, and laying such emphasis on this or that subject in medicine as seemed to him interesting and important. There is evidence that at this time he joined E. E. Southard in a fairly regular attendance on the seminar of Professor Josiah Royce in philosophy. Although Henderson's attentions to medical courses were not to prepare him for medical practice, they did yield him an appreciation of the rôle of medicine in the development of science and gave him contacts and understandings which later proved highly valuable to his thinking and achievement.

On receiving the M. D. degree in 1902 he went to Hofmeister's laboratory in Strassburg where he spent two years in an atmosphere of research in biological chemistry. There is question as to whether he received any formal advantage from his experiences there; an associate has testified that he was prone to wander about the laboratory and converse and theorize with other advanced students, especially concerning the methods they were using and the results they were obtaining. During these two years he established friendships which were lifelong. And he began a study of the properties of hemoglobin which he was later to develop into an elaborate system. His observations of subserviency and obsequiousness to authority, as characteristic German traits, resulted in abiding dislike for these aspects of German character.

On returning to the United States he was appointed Lecturer in Biological Chemistry at the Harvard Medical School. Thus began an association with the University which lasted throughout his career. In his years of service to Harvard he was Lecturer one year (1904–5), Instructor from 1905 until 1910, Assistant Professor of Biological Chemistry from 1910 until 1919, Professor from 1919 until 1934, and Abbott and James Lawrence Professor of Chemistry from 1934 until his death.

The span of Henderson's professional career was marked by development in fairly distinct stages. The first was devoted to the application of physical chemistry in explaining the maintenance of neutrality in body fluids, specifically in blood—culminating in a classic paper, "Das Gleichgewicht zwischen Basen und Säuren im tierischen Organismus" (1909). Out of this interest there evolved thoughtful consideration of the relations of organisms to their surroundings, a consideration which resulted in two volumes, "The Fitness of the Environment" (1913) and "The Order of Nature" (1917). Illustrating a further development of his insight and marking intermediate progress between his earlier and his later studies was an exhaustive examination of blood as a complex, multifunctional system; it was reported in the treatise, "Blood, A Study in General Physiology" (1928). Finally, he was concerned with the more complex relationships of organisms, but human beings now, on the social

level. Again a book outlined his thinking—"Pareto's General Sociology, A Physiologist's Interpretation." Throughout the decades of his devotion to Harvard University he proved to be a highly effective instigator and supporter of new ventures in its educational and institutional developments. His election as Foreign Secretary of the National Academy of Sciences brought into usefulness his wide acquaintance with European scientists and his constructive foresight. In what follows, these various aspects of Henderson's life history will be taken up in their order.

Neutrality Regulation, and Blood as a Physico-chemical System. When Henderson returned from Europe in 1904 he worked first on the relation of heats of combustion to molecular structure and published a number of researches in that field. It is clear, however, that by 1906 the acid-base equilibria in solutions and in body fluids were beginning again to attract his attention. In that year appeared a paper on equilibrium in phosphate solutions, in 1907 two papers on neutrality preservation in the animal organism, and in 1908 an array of publications on the same topic, including one on a theory of neutrality regulation and, significant of later devices, one on a diagrammatic representation of equilibria between acids and bases in solutions. These studies led to a disclosure of the remarkable properties of carbonic acid in maintaining a neutral reaction whenever it exists in solution with its salts, provided an excess of the acid is present. Any acid, even slightly weaker or stronger than carbonic acid, lacks that property. The hydrogen-ion concentration in the blood, as Henderson pointed out, depends upon the ratio of carbonic acid to sodium bicarbonate. If in the course of metabolism a strong nonvolatile acid (e.g., lactic acid) enters the blood, it unites with the base, thus liberating carbonic acid, which, however, escapes through the lungs, so that the ratio is preserved. Thus the blood, slightly alkaline, remains slightly alkaline notwithstanding the continuous discharge into it of acid metabolites.

His discovery of the extraordinary capacity of carbonic acid to preserve neutrality in an aqueous solution had far-reaching influences on Henderson's thinking. It led him to consider its

rôle in the ocean and in the waters of the earth, and it led also to detailed further investigations of the mechanisms of adaptation in blood, regarded as a physico-chemical system.

The selection of blood as a subject of elaborate studies seems to have been due to a desire to apply to a recognized bodily tissue, possessing some of the general characteristics of protoplasm, having well defined functions, and yet being practically free from the complications of metabolic processes, the exact methods of chemical research. This Henderson and his collaborators continued to do through many years. In the course of the prolonged investigation he came upon the memoir of Willard Gibbs, "On the Equilibrium of Heterogeneous Substances" (which he characterized as "the greatest effort at sustained abstract thinking in the history of America"), an essential aid in mathematical treatment of the shifting variables of blood. Later he found the nomographic method of d'Ocagne, of representing graphically and quantitatively the interrelations among the numerous reacting constituents of blood, an indispensable means of illustrating the system as a whole.

When Henderson was Harvard Exchange Professor for France, in 1921, he presented the first summary of his monumental investigation of blood from the point of view of the physical chemist. A full account was given in the Silliman Lectures at Yale University and published, as previously noted, under the title, "Blood, A Study in General Physiology." The treatise begins with an inventory of the aspects of general physiology to which the respiratory functions of the blood are related. Then the chemical composition was so defined that a roughly approximate quantitative study of blood as a physico-chemical system was possible. Thereupon followed a consideration of the partial activities previously recognized in the system and a nomographical synthesis of these activities into a description of the conditions of equilibrium in a single specimen of blood. The nomogram thus obtained was then used to define and to analyze the internal shifts in the various factors during a respiratory cycle of the blood flow. Thereby it became possible to consider the relations between the properties of blood and its cycle, and also the functional adjustments of the respiratory and the circulatory

activities. Furthermore, the account illustrated how the methods could be used to describe quantitatively the system as altered by a change from rest to work, by disease, and in varieties of animal species.

Although the delineation of the interplay of oxygen, carbon dioxide, water, proteins, and of hydrogen and chloride ions in corpuscles and in plasma, as the blood streams to and fro between lungs and tissues, was an eminent and masterly achievement, Henderson recognized that it was "still very imperfect". It was, however, a splendid effort towards understanding the intimate interrelations of physiological processes—an understanding made possible by mathematical analysis of carefully measured factors. Despite the incompleteness of the description of the complicated events occurring in the relatively simple conditions in blood, and despite the admission that the organism as a whole is "an immensely complex system in equilibrium," the belief was expressed that "the time must come when the science of pathological physiology, conceived as the study of the mutual dependence between many variables, will afford descriptions of disease that partly meet the long-felt needs of physicians."

"The Fitness of the Environment" and *"The Order of Nature."* These two volumes devoted to discussions of large general problems, global and even cosmic in scope, may be said to have had their origin in the deep impression made on Henderson by the remarkable properties of carbonic acid and water, already referred to as an introduction to his study of the equilibria in blood.

In the first of the volumes Henderson pointed out that Darwinian fitness implies a mutual relationship between the organism and the environment—the latter quite as essential as the fitness developed in the course of organic evolution. And the argument which he supported was that in fundamental characteristics the actual environment is the fittest possible abode for living beings. The argument ran as follows.

Living beings as mechanisms are complex and physico-chemically well regulated systems, in an environment which is also physico-chemically well regulated. Between organisms and their

environment there is a continuous interchange of matter and energy. The primary constituents of the natural environment, water and carbonic acid, are necessarily and automatically formed in vast amounts by the cosmic process. Water and carbonic acid (and their constituent elements) display an extraordinary fitness for their biological rôle. Thus water, because of its remarkable heat capacity, heat conductivity, its expansion on cooling near the freezing point, its reduced density as ice, its heat of fusion, heat of vaporization, its vapor tension and freezing point, its unique solvent properties, its dielectric constant and ionizing power, and its surface tension, render it in certain respects maximally fit for living beings. Thereby it assures conditions for constancy of temperature, richness of the organism in chemical constituents, variety of chemical processes, electrical phenomena and the functions of colloids. Carbon dioxide, also, possesses very unusual properties. Its wide distribution and high absorption coefficient render its association with water wellnigh universal; its property of preserving a neutral reaction when in solution with its salts maintains the neutrality or slight alkalinity of the ocean and also the chemical inactivity of circulating water much as it does in circulating blood. Furthermore, chemical compounds containing the elements found in water and carbon dioxide—carbon, hydrogen and oxygen—display unique properties, in that they are formed in vast numbers and varieties and complexities, with many kinds of relations and reactions, heats of reaction and instability, so that they become sources of matter and energy for bodily metabolism, sources of complex bodily structure, and means of performing complex functions. "From the materialistic and the energetic standpoint alike, carbon, hydrogen and oxygen, each by itself and all taken together, possess unique and preeminent chemical fitness for the organic mechanism. They alone are best fitted to form it and to set it in motion; and their stable compounds, water and carbonic acid, which make up the changeless environment, protect and renew it, forever drawing fresh energy from the sunshine."

The physical and chemical properties, thus considered, include nearly all known to be of biological importance or apparently related to the complexity, regulation and metabolism of living

beings. No other compounds show more than a few of the qualities of fitness of water and carbonic acid; no other elements show those of carbon, hydrogen and oxygen. And none of the characteristics of these substances is known to be unfit or considerably inferior to the same characteristics in any other substance. The fitness of the environment is therefore both real and unique—it is "the best of all possible environments for life."

That this conclusion raises questions regarding the significance of fitness, both in biology and in cosmology, Henderson clearly recognized. His discussion of teleology will be deferred, however, until the second of the two books has been surveyed.

"The Order of Nature" is an extension of the thinking, the evidence and the ideas which were expounded in "The Fitness of the Environment." The discussion, however, centers about the importance of the three elements, carbon, hydrogen and oxygen, for the process of cosmic evolution, i.e., with biological considerations omitted and emphasis laid on a foundation of physical science.

The argument to be presented had philosophical as well as scientific bearings. As an introduction Henderson sketched philosophical theories regarding the problems of natural organization and teleology, tracing the views of Aristotle, Bacon, Descartes, Leibnitz, Hume, Kant, Goethe, Bernard, Roux, down to Driesch, Haldane and Bosanquet. The problem was that of reconciling mechanism in natural phenomena with the indications of purpose. "The teleological appearance of the world" is "something that is real"; the solar system, the meteorological cycle and the organic cycle give an "impression of harmony which corresponds to an order in nature." Here is a challenge to scientific research—"What is the mechanistic origin of the present order of nature?" The answer to that question, Henderson declared, "may be approximately solved by discovering, step by step, how the general laws of physical science work together upon the properties of matter and energy so as to produce that order."

At this point the contributions of Willard Gibbs, rigorously defined and mathematically analyzed, are invoked. The world is a world of systems, each system with its phases—solid, liquid

or gaseous—and with its stable chemical components. All forms of energy and activity are involved in the definition of systems, temperature and pressure being of very general importance. And the degree of concentration of each component in each phase is recognized as essential to the description of a system. By mathematical treatment Gibbs showed that the greater the number of phases the smaller the number of kinds of variation (i.e., the fewer degrees of freedom) which can occur in a system. Other things being equal, the stability of a system *increases* with the number of phases and also with the number of restrictions upon the intensity of energy (e.g., temperature) and upon the concentrations. And, other things being equal, this stability of a system *diminishes* with increase of its undecomposed constituent molecular species, and of the number of different forms of energy (e.g., heat, pressure, surface tension) which are involved in its activities. These abstract categorical statements are illustrated by examples.

When the earth was in a molten state it was in what may be regarded as a single system with a small number of phases. The components, however, were at least as numerous as the chemical elements (i.e., 90 or more). This is a condition highly unstable. "In the course of evolution of the earth, systems have evolved in great profusion, with almost infinite diversity in phases, components, concentrations, and activities, and always in coordination. This, indeed, abstractly stated, is the very essence of the evolutionary process." And it has established a relative stability in a relative diversity in contrast to the original state. This summary has a resemblance to Herbert Spencer's definition of the course of evolution—a resemblance which led Henderson to a critical and luminous evaluation of Spencer's ideas.

The myriads of variations of material forms on the earth are not due solely to the *process* of multiplying systems; they are also to be ascribed to the diversity of the components of the systems—the 90-odd elements capable of entering into a great variety of chemical reactions. The problem which presents itself, then, is that of determining the properties of matter and energy which serve for the construction of every kind of system in the whole range of their diversity.

Mainly the phenomena of terrestrial evolution have occurred on the surface during the existence of the crust. In the formation of the crust, as a resultant of gravitational force, lighter elements would be driven in relatively great concentration to the periphery, especially hydrogen, carbon, nitrogen, oxygen, sodium, magnesium, aluminum, silicon, chlorine, calcium and iron. "These elements of low atomic weight are generally more intense and more diverse in their chemical activity"—thus providing possibilities of chemical changes at primitive stages of differentiation. The atmosphere early contained light elements, hydrogen, carbon, nitrogen, and oxygen, and later nitrogen and the chemical combinations, water vapor and carbon dioxide. As the earth cooled, water began to condense from the atmosphere—water the most powerful and most universal agent in moulding the earth's surface. By action of the meteorological cycle water and carbon dioxide have formed streams, lakes, the ocean, and laid down strata and soil; indeed, they have provided nearly everything that meets the eye, except living things and the products of living things.

Of all the chemical elements, hydrogen, carbon and oxygen possess the greatest number of compounds, enter into the greatest variety of reactions, and afford by far the greatest number of components for the constitution of systems. Their properties permit to a conspicuous degree *freedom of development.* These unique properties favor "the widest range of durability and activity in the widest range of material systems—in systems varying with respect to phases, to components and to concentrations." The resultant environment is the fittest possible, for durable mechanisms, whether living beings or steam engines.

The significance of all this, in Henderson's conception, he defines as follows:

"The process of evolution consists in an increase of diversity of systems and their activities in the multiplication of physical occurrences, or, briefly, in the production of much from little. Other things being equal, there is a maximum 'freedom' for such evolution on account of a certain unique arrangement of unique properties of matter. The chance that this unique ensemble of properties should occur by 'accident' is almsot infin-

itely small (i.e., less than any probability which can be practically considered). The chance that each of the unit properties of the ensemble, by itself and in cooperation with others, should 'accidentally' contribute to this 'freedom' a maximal increment is also almost infinitely small. Therefore, there is a relevant causal connection between the properties of the elements and the 'freedom' of evolution. So at least the mind of man always argues when confronted by a group of facts which are very improbable as chance occurrences *and also* peculiarly related together. But the properties of the universal elements antedate or are logically prior to those restricted aspects of evolution which are within the scope of our present investigations and with which we are concerned. Hence we are obliged to regard this collocation of properties as in some intelligible sense a preparation for the process of planetary evolution. For we cannot imagine an interaction between the properties of hydrogen, carbon and oxygen and any process of planetary evolution or any similar process whereby the properties of the elements as they occur throughout the whole universe should have been modified. Therefore, the properties of the elements must for the present be regarded as possessing a teleological character."

"The teleological appearance of nature depends upon an unquestionable relationship between certain original characteristics of the universe which, because it is *merely* a relationship and in no sense a mechanical connection, because it is unmodified by the evolutionary process and changeless in time, is to be described as teleological ('design and purpose are not in question': footnote). In other words, the appearance of harmonious unities in nature, which no man can escape, depends upon a genuine harmonious unity that is proved to exist among certain of the abstract changeless characteristics of the universe."

In discussing the appearance of teleology, in "The Fitness of the Environment", Henderson offered the vitalists a dilemma. There are two evolutionary processes resulting in two complementary fitnesses, the fitness of the physical environment and the fitness of organisms to that environment. The vitalists argue that the latter cannot be explained on mechanistic grounds and assume the necessary operation of an extraphysical influence. But if they assume that necessity for one fitness they must assume it for the other. Thus the distinction between the organic and the inorganic would disappear and there would be no "vitalism", only universal teleology.

Henderson left the teleological arrangement, in his own definition, as an ultimate and mysterious empirical fact. Science is still free to continue without interference to search after mechanistic explanations of natural phenomena, for that appears to be the character of the processes in nature; and all may wonder at the harmonies which have slowly evolved from chaos, for they appear to have resulted from a pattern which the processes have followed.

In the foregoing summary of "The Fitness of the Environment" and "The Order of Nature" it has been impossible to convey the great ranges of knowledge—in chemistry, cosmology, philosophy and biology—as well as the broad sweep of imagination, the originality, the stimulating suggestiveness, and the close reasoning which were displayed. Doubtless the two courses, "Biological Chemistry" and "History of Science", offered to Harvard students, provided both subjects and occasions for repeated enriching surveys and for fruitful debate. Continued attendance on a philosophical seminar conducted by Josiah Royce had helped to satisfy an interest in the deeper implications of phenomena. And study of Willard Gibbs's "Equilibrium of Heterogeneous Substances" called for intensive and precise attention. From these sources of information and methods of self-discipline his students greatly profited as his courses revealed the progress of Professor Henderson's own development. For example, in 1912, he read a large part of "The Fitness of the Environment" to the class in biological chemistry—before he finished the book. "Thus he managed", so one of his associates has testified, "to preserve vigor and freshness in each of these courses over extended periods, and because of the unusual breadth of his learning, students gained not only special knowledge but also were given an insight into the cultural meaning of science."

Interest in Human Relations. Henderson himself has told of being introduced, about 1928, to Pareto's "Trattato di Sociologia Generale" (1916) by William Morton Wheeler, who advised giving it careful examination. Unlike other writers on the so-called social sciences, Pareto was trained in mathematics and in physical science, had had experience as a practical engineer,

had dabbled in Italian politics, and had taught economics. He brought to his study of sociology, therefore, direct knowledge of varied aspects of human behavior and a carefully disciplined intelligence. The effect on Henderson was immediate and highly stimulating. He became convinced that the treatise was "a work of genius" and that acquaintance with Pareto's ideas and methods "is at present indispensable for a wide range of phenomena, whenever and wherever men act and react on one another." It is likely that Pareto's analysis of human motives appealed to Henderson because it resulted in the construction of a system in which there were variable constituents influencing one another. Indeed, though emphasizing that the analogies were accidental, Henderson pointed out that Pareto's social system has many of the logical advantages—and limitations—present in a physico-chemical system. The "social system contains individuals; they are roughly analogous to Gibbs's components. It is heterogeneous (cf. Gibbs's phases), for the individuals are of different families, trades, and professions; they are associated with different institutions and are members of different economic and social classes. As Gibbs considers temperature, pressure, and concentrations, so Pareto considers sentiments, or, strictly speaking, the manifestations of sentiments in words and deeds, verbal elaborations, and the economic interests."

In 1932 Henderson was invited to conduct a seminar on Pareto in the Harvard Department of Sociology. He undertook the task and continued the seminar regularly thereafter. In 1934, under Henderson's inducement, two of his disciples, C. P. Curtis and G. C. Homans, issued a small expository volume, "An Introduction to Pareto, His Sociology." And in 1935, Henderson himself outlined and commented on Pareto's ideas in his last published book, "Pareto's General Sociology, A Physiologist's Interpretation." The next year he began a course called "Concrete Sociology," in which, after about a half-dozen lectures, explaining Pareto's conceptual scheme and tentative uniformities, he introduced a series of lecturers, each of whom presented a "case." Thereupon, in discussion with the students, he would point out how the individual case would be interpreted by Pareto's methods. Because of the extraordinary range of his

reading and observations Henderson was able to maintain a consistent consideration of the social problems and thereby to help render the study of sociology concrete and specific.

It seems probable that Henderson's early concern with scientific questions contrasted so sharply with the much less definite considerations which he encountered commonly in subjects involving human relations that he was impelled to insist on exact thinking and exact definitions. Thus he undertook a meticulous inquiry into what is meant by a "fact"—an inquiry modestly entitled "An Approximate Definition of Fact." Again, in a discussion of what is meant by the term "social progress" he vigorously argued that it is meaningless because the sentiments and rationalizations of those who use it are so deeply and so diversely implicated that it can have no clear correspondence with reality. Insistence on clarity and "concreteness" as a basis for proper understanding led Henderson, in a thoughtful paper, "The Study of Man," to contrast the procedures of medicine with those of sociology. Medical scientists have intimate, habitual and intuitive familiarity with things; they know things systematically; they have a way of thinking about things effectively in a way rare among social scientists. Systems in the medical sciences resemble systems in other natural sciences; systems in the social sciences commonly resemble philosophical systems. Sentiments do not ordinarily intrude in the thinking of medical scientists; they do so in the thinking of the social scientists. In the medical sciences special methods and special skills are many; in the social sciences, few. Finally, in the medical sciences, by continuous observation and experiment, theories and generalizations are constantly being corrected, modified and adapted to phenomena, and fallacies are being eliminated; in the social sciences there is little of this adaptation and correction.

That Henderson did not look upon practical medicine uncritically is indicated by his offering a voluntary course to first-year medical students on the relations between doctor and patient. "A physician and a patient make up a social system," he wrote. And with the students he considered cases as he did in his course on Concrete Sociology, using Pareto's concepts of the motivation of human behavior. Thus novices in medicine,-as well as young

men in sociology, history, and government came under his instructive and stimulating influence.

Creative Achievements, Educational and Societal. Henderson was not only a productive scholar and an interpreter of natural phenomena; during his long service in Harvard University he was also an effective contributor to important establishments in the University organization and to extramural enterprises.

In 1909 he and his close associate in the Royce seminar, E. E. Southard, called attention to the cultural value of the so-called "medical sciences"—biochemistry, physiology and others—which were not then adequately represented in the College, and they argued that these sciences were satisfactory subjects for study by academic students. This propriety had long been recognized in the State Universities of the mid-west, with the consequence that in them the baccalaureate and medical degrees could be obtained in six years whereas at Harvard eight years were required, since the baccalaureate was prerequisite for entrance to the Medical School. The article caused much comment at the time, and although recognition of the illuminating possibilities of study of the medical sciences was not immediately granted by the University, there was an abatement of the rigors of the entrance requirements, and later an offering of physiology and biochemistry (the latter by Henderson himself) to the undergraduates of Harvard College.

An important development at the Medical School for which Henderson was responsible was the founding of the Laboratory of Physical Chemistry. An invitation for him to go to another university, in 1920, raised the question as to whether opportunities could be offered which would keep him at Harvard. Among his desires was a laboratory in which his ideas could be tested. Such a laboratory was equipped in close relation to the Department of Physiology. Associated with Henderson was Dr. Edwin J. Cohn who had collaborated with him in 1917-18 in a research on the acid-base equilibrium in sea water and later on the prevention of "ropey bread", and who then began illustrious investigations of the physical chemistry of proteins.

The setting up of the Fatigue Laboratory in the Harvard School of Business Administration was another consequence of

Henderson's creative imagination. It accompanied the curious transition of his interests from concern with physico-chemical conditions in the external and the internal environment of organisms to concern with questions of sociology. The change of emphasis, which was gradual, was an outgrowth of an increasing recognition of highly significant psychological and physiological influences affecting the behavior of human agents in industry. He had been a student of the organization of the body; he became a student of the organization of society and the interplay of its elements. Dean Donham, of the Business School, who was intimately acquainted with the shift of interest, has written a revealing account of it:

"From about 1922 it was my good fortune to know Henderson well. As I came to appreciate the encyclopedic and imaginative qualities of his mind and his combination of learning with the highest degree of intellectual honesty, I fell into the habit of discussing with him the wider implications of the task facing a school of administration. Up to that time his intellectual interests had been focused on science—particularly on biochemistry and the history of science. In 1924–25 his interests in our problems became aroused, and he acquired an understanding of the dangers to organized society which arises from the specialized emphasis of the modern world on technological advance and the relative neglect by men of affairs of human problems which arise from such advance. In the fall of 1925 he came to see clearly the serious threat of these dangers to the future of science itself. His interest in such topics was stimulated further by Professor Elton Mayo after the latter joined the Faculty in 1926, to study 'Human Problems of Administration.' Dr. Henderson soon realized the advantages which might arise from backing up this work with work in human biology. In 1927, with the support of the Rockefeller Foundation, he established the Fatigue Laboratory at the school and moved his office here where he could be in continuous contact with, and collaborate in, our work in human problems. This association was important, happy and mutually stimulating."

Henderson's last and highly valuable contribution to the advancement of scholarship at Harvard was the exercise of his influence in establishing the Society of Fellows. For some time he had been impressed by the remarkable number of distinguished scientists who came from Trinity College, Cambridge,

and had been thinking of the possibility of developing at Harvard a means of giving recognition and advantages to the most promising young graduates—an American equivalent but not a copy of the Trinity Prize Fellowships. He found a sympathetic collaborator in President Lowell who had been impressed by a similar idea years before at a meeting of the Fondation Thiers in Paris. The plan which was finally evolved arranged for a small group of Senior Fellows from the professorial staff, who were eminent scholars, and a group of twenty-four Junior Fellows, selected by the Senior Fellows for outstanding originality in their various fields. The Juniors were given stipends for a three-year term (renewable in some cases), that freed them from burdensome teaching and from economic worries. They were assured complete exemption from any academic requirements. Thus they were enabled to utilize all the resources of the University in the exercise of their gifts and skills at a time of life when achievement in productive scholarship is personally most influential. Every week a dinner, attended by the Senior and the Junior Fellows, brought together the novitiates in research and the accomplished and recognized leaders. From the first Henderson was chairman of the group. His wide reading, his intimate acquaintance with many fields of knowledge—mathematics, medicine, biology, philosophy, history, literature—and his well-formulated and stimulating ideas made him an ideal person to promote that interaction of minds which gives zest to the intellectual life.

In 1936 Henderson was elected Foreign Secretary of the National Academy of Sciences. During the summer of 1937 he visited Germany, France and England to learn what might be done to promote closer cultural relations between the Academy and scientific bodies in those countries. In Germany and France he found little to encourage him. In England, however, conversations with A. V. Hill, then a Secretary of the Royal Society, and with Sir Henry H. Dale, Sir Albert Seward, Foreign Secretary of the Society, and President Bragg, led to two results. The first was an arrangement whereby members of the National Academy and of the Royal Society would each welcome members of the other organization at meetings and would exchange

occasional special programs and announcements of special activities. The second arrangement was for an annual alternate exchange of lecturers between the two countries—a representative of the Royal Society in Washington one year, and a representative of the National Academy in London the next year, and so on. The title "Pilgrim Lectureship" was proposed and accepted, and the trustees of the Pilgrim Trust in London offered £250 per year for six years to pay traveling expenses of the lecturers. Henderson was to have been the first Pilgrim Lecturer for the Academy, in June, 1940, but illness prevented his going to London. President Bragg was Pilgrim Lecturer for the Royal Society at the Academy meeting in Washington, in April, 1941, and thereby initiated the friendly intercourse which Henderson projected.

Life Events and Personal Characteristics. Many of the occurrences in Henderson's life have already been mentioned in the description of his scholarly achievements. Besides being Lowell Institute Lecturer (1912), Exchange Professor for France and the French Provincial Universities, and Silliman Lecturer at Yale University, he was Leyden Lecturer at the University of Berlin (1928) and Mills Lecturer at the University of California (1931). His eminence as a contributor to science was widely recognized by the bestowal of honorary degrees and by election to learned societies. He received the S.D. degree from Harvard University (1932), and from the University of Cambridge (1934), and the LL.D. from the University of Pennsylvania (1940). France made him a member of the Legion of Honor. He was a Fellow of the American Academy of Arts and Sciences, a member of the Association of American Physicians, the American Philosophical Society and various American scientific organizations related to his interests—the Physiological Society, the Society of Biological Chemists and the Chemical Society. In addition he was a corresponding member of the Académie de Médecine of Paris, honorary member of the Societá Italiana di Biologia Sperimentale, and foreign member of the Deutsche Akademie der Naturforscher of Halle.

In 1910 he married Edith Lawrence Thayer, and a son was born to them, Lawrence Joseph, Jr. The solitude of the later

years of his life, due to his wife's incurable invalidism, he bore with admirable fortitude.

Physically Henderson was of the pyknic rather than the asthenic type. He carried considerable overweight for his height. He enjoyed the pleasures of the table and took pride in his judgment of fine vintages. Although he participated in sports as a boy, he made little use of his muscles as a man. He was a lover of natural beauty. At his summer camp bordering a small lake in Morgan Center, Vermont, he found deep contentment in the loveliness of the scene, the comradeship of friends and neighbors and in reflective contemplation. In the main his health was good. While Mills Lecturer at the University of California, however, he suffered a severe hemorrhage from a duodenal ulcer, which required for some time a careful regimen. His sudden death, February 10, 1942, was due to a pulmonary embolus, following an abdominal operation.

Although Henderson contributed in various and important ways to the advancement of science, he was not facile in experimentation. He was a master strategist rather than an expert in tactics. One of his students has written "He never bothered to demonstrate correct methods but let me work out my own salvation." That was typical. When the observations were reported to him, he took great pains in examining them, and "his interpretation was always most interesting and sound." That again was typical. In outlining a project and later in perceiving the significance of the results he was superb.

In conversation Henderson was forceful and positive. He enjoyed argument and often deliberately employed dogmatic statements in order to shock his audience into a basic reexamination of their opinions. At the weekly meetings of the Society of Fellows he was always leading animated discussions, expounding his views with much vigor and often overwhelming his opponents by sheer personal force. Politically an extreme conservative, he found in Pareto strong backing for a distrust of liberals and reformers.

In the report to his college class 25 years after graduation Henderson wrote that the satisfactions of his life had flowed from the tranquil experiences of a university professor. Search

for new knowledge and "occasional success in the quest," personal association and friendship founded on common interest with men at home and abroad, and "now and then the possibility of helping a younger man on his way" were items in his "satisfactions." The younger men whom he helped have taken prominent places in science, in medical practice and teaching, in research, in history and business, and in social studies—the most perfect tribute which could be paid to his pervasive kindness and to his sympathetic and persistent concern for their welfare and success.

KEY TO ABBREVIATIONS IN BIBLIOGRAPHY

Am. J. Phys. = American Journal of Physiology.
Am. Nat. = American Naturalist.
Ann. Rev. Phys. = Annual Review of Physiology.
Arch. f. exp. Path. Pharm. = Archiv für experimentelle Pathologie und Pharmakologie.
Arch. Int. Med. = Archives of Internal Medicine.
Biochem. Ztschr. = Biochemische Zeitschrift.
Ergeb. Physiol. = Ergebnisse der Physiologie, biologischen Chemie und experimentellen Pharmakologie.
Handb. d. biol. Arbeitsmet. = Handbuch der Biologischen Arbeitsmethoden.
Har. Alumni Bull. = Harvard Alumni Bulletin.
Har. Bull. = Harvard Bulletin.
Har. Bus. Rev. = Harvard Business Review.
Har. Grad. Mag. = Harvard Graduates' Magazine.
J. Am. Chem. Soc. = Journal, American Chemical Society.
J. Biol. Chem. = Journal of Biological Chemistry.
J. Gen. Phys. = Journal of General Physiology.
J. Ind. Hyg. & Tox. = Journal of Industrial Hygiene and Toxicology.
J. Med. Res. = Journal of Medical Research.
J. N. E. Water Works Assn. = Journal, New England Water Works Association.
J. Pharm. & Exp. Therap. = Journal of Pharmacology and Experimental Therapeutics.
J. Phil., Psy. & Sci. Meth. = Journal of Philosophy, Psychology and Scientific Methods.
J. Phys. Chem. = Journal of Physical Chemistry.
Klin. Wochschr. = Klinische Wochenschrift.
La Presse Méd. = La Presse Médicale.
N. E. J. Med. = New England Journal of Medicine.
Phil. Rev. = Philosophical Review.
Proc. Am. Acad. = Proceedings, American Academy of Arts and Sciences.
Proc. Am. Phil. Soc. = Proceedings, American Philosophical Society.
Proc. Am. Soc. Biol. Chem. = Proceedings, American Society of Biological Chemistry.
Proc. Nat. Acad. Sci. = Proceedings, National Academy of Sciences.
Proc. Soc. Biol. Chem. = Proceedings, Society of Biological Chemistry.
Q. Rev. Biol. = Quarterly Review of Biology.
Sci. Mo. = Scientific Monthly.
Trans. Assn. Am. Phys. = Transactions, Association of American Physicians.
Yearbook Am. Phil. Soc. = Yearbook, American Philosophical Society.
Ztschr. phys. Chem. = Zeitschrift für physikalische Chemie.

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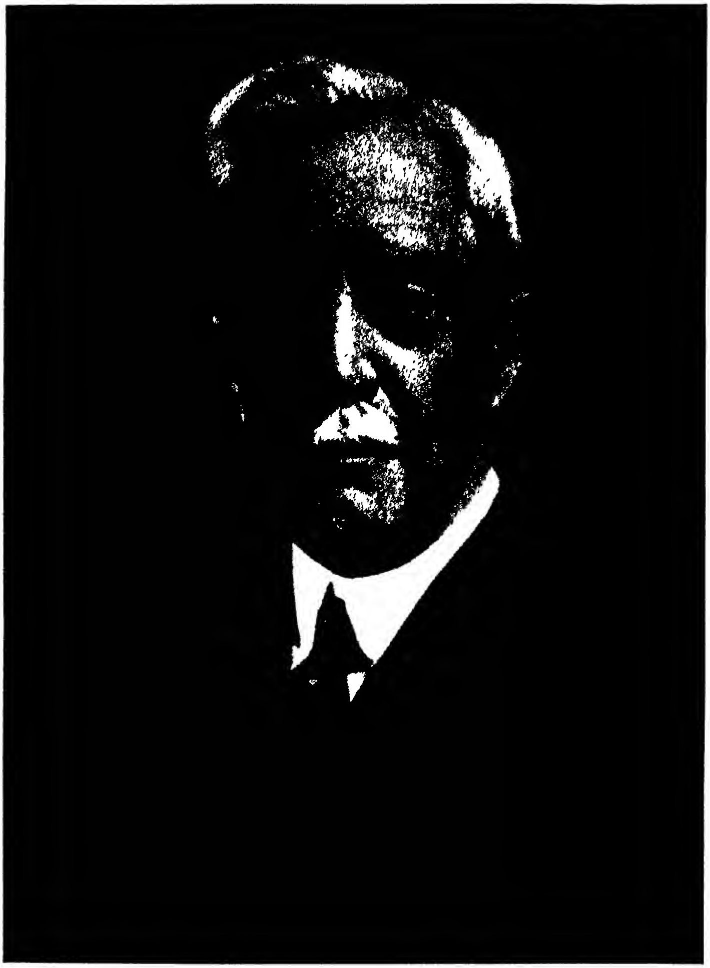

Dayton C. Miller

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BIOGRAPHICAL MEMOIR

OF

DAYTON CLARENCE MILLER

1866–1941

BY

HARVEY FLETCHER

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING 1943

DAYTON CLARENCE MILLER

1866–1941

BY HARVEY FLETCHER

When Dayton C. Miller entered upon the scientific scene around 1890 the opinion of at least one prominent scientific figure was that further progress in physics would be limited to the "fourth decimal place." Miller's decision to take up acoustics as his chief activity was not only remarkable in view of this opinion but even more remarkable in that the work of Rayleigh had been so thorough and comprehensive that it seemed indeed that nothing further was to be done in the field of acoustics. That he was able to achieve so much is striking tribute to the perspicacity and industry which so distinguished him.

Dr. Miller was prominently connected with the beginning of the renaissance in the science of acoustics which has been going on with increasing momentum during the last quarter of a century. Notable contributions were made particularly to the parts called musical acoustics and architectural acoustics. Also the general field of physics was not neglected.

Dayton C. Miller was born in Strongville, Ohio, on March 13, 1866, the son of Charles Webster Dewey and Vienna (Pomeroy) Miller. He had the good fortune of having his early boyhood training on a farm where his early interest and ingenuity in making things had a chance for expression. When Dayton was eight years old the Miller family moved to Berea, Ohio, where the father operated a hardware store at the back of which was a tin shop. These facilities provided Dayton with mechanical tools which he learned to use in his early boyhood and soon he became very proficient in building complicated mechanical things. Among these are three astronomical telescopes, the last one being a 5-inch refractor which is now at the Case School of Applied Science.

Miller's father prospered at Berea, becoming identified with banking and later with the electric traction business. Dayton's natural love of music was fostered very much since his mother

played the organ and his father sang in the church choir. At thirteen we find him with his first flute, one made of silver. This was a forerunner of a great collection of flutes, about which we will hear later. His dual interest in music and science was early shown by the contribution made at the commencement exercises at Baldwin University, where he graduated in 1886. At that time he gave a lecture on the sun and played a solo on his silver flute. After graduation he spent fifteen months as assistant cashier in his uncle's bank at Berea. The life of a banker seemed to be a dull one to him so he left this position and went to Princeton for postgraduate work in astronomy, studying under Professor Young. After completing one year of graduate work he returned again to his Alma Mater for a year's teaching. The pull of research however was too strong so the next year saw him again at Princeton, where he finished his work for the doctorate, receiving the degree of Doctor of Science from that institution in the spring of 1890, having finished all the work for the doctorate within two years.

Miller's excellent record won for him the appointment to the newly founded Thaw Fellowship in Astronomy at Princeton. However, the difficulty of having certain glass prisms molded and properly ground made it necessary to postpone active work in the capacity of Fellow for a year after the appointment. This forced delay may seem like a trivial incident in his life but as so frequently happens it was this delay that changed the whole course of his career. Instead of developing in astronomy at Princeton, Dr. Miller accepted a teaching position at the newly formed Case School of Applied Science in Cleveland, back in his native state. No doubt he thought that the job assigned to him, which was the teaching of elementary mathematics, was temporary and that at the end of the year he would return to Princeton. However, he proved to be such an excellent teacher that he was induced to stay at Case School and indeed he spent the rest of his professional life there (51 years).

After three years in the department of mathematics Dr. Miller was asked to take charge of the work in physics while they were looking for a man to replace Dr. Reid as professor of

physics. And thus through these circumstances he was started on a career in physics. It is needless to say that no one was found to replace him in the physics department and at the end of his first year he was promoted to the rank of Assistant Professor. His confidence of success in this field at this time was shown by his getting married to Edith Easton of Princeton, New Jersey.

His experimental skill was first shown by the remarkable X-ray photographs which he took only a few months after Roentgen announced his discovery. For this purpose Dr. Miller used some of the Crookes and Geissler tubes which he had purchased at the World's Fair in Chicago three years earlier. Dr. Crile of the famous clinic in Cleveland bearing his name heard of these photographs and promptly brought one of his patients with a broken arm to be photographed by the new X-ray technique. This was probably the first X-ray photograph of surgical importance that was made. Later, with the help of Dr. Miller's technique, bullets were located and the shape of impacted teeth indicated.

The famous Michelson-Morley experiment which was designed to measure the velocity of the earth through ether and which laid the experimental foundation for the theory of relativity was performed in 1887 at Case School. This was just three years before Miller entered the school as a young teacher. The Millers and the Morleys became warm friends as they lived neighbors in the same apartment building. In 1900 they went to Paris to attend the International Science Congress, at which time they met the famous Lord Kelvin. He urged them to repeat the ether-drift experiment, so immediately on their return a series of measurements was started which lasted for several years. A small positive effect was obtained which Miller always insisted was real. The development of the theory of relativity revived and increased the importance of the question, and Miller's conscientiousness made him decide that a repetition of the experiment with improvements was called for. This he did, carrying out much of the work at the observatory on Mount Wilson. Such was his industry that he personally made more than 100,000

readings and obtained a small but definite positive result which in his mind vitiated the postulate of the theory of relativity.

The Rockefeller Laboratory of Physics at Case School which was built in 1904 was planned by Professor Miller. The equipment used in this building for his famous demonstration-lecture courses was purchased by him during a special trip to Europe in 1905. He developed remarkable skill in his teaching technique and in his many public lectures for utilizing such demonstration apparatus to make the facts of science live.

Dr. Miller's love for music was deep, particularly for the opera and for the symphony. It is said that he heard Parsifal performed 23 times. The Millers made frequent trips to Bayreuth, Germany, for the Wagnerian Festival. He was an expert performer on the flute, pipe organ and piano, and he composed thirty-one pieces for these instruments. This love of music naturally orientated his scientific investigations into the field of acoustics. Miller wanted to know how the physical characteristics of musical tones were related to the various musical qualities of the tone. He also wanted to know what were the physical factors which made an auditorium good or bad for musical performances. On both of these questions he became an expert.

To investigate the first question he invented the Phonodeik which records the pressure of sound as a function of time. Not only did Miller use this instrument as a research tool in his laboratory but, because of the great popular interest that it aroused, he gave public lectures all over America and Europe using the Phonodeik to throw on a screen the speech wave patterns produced by various spoken words and other sounds. One very important conclusion which was drawn from his experiments made with the Phonodeik on vowel sounds was that the character of a vowel sound depends only upon frequency regions which are independent of the pitch at which the vowel is sounded.

Professor Miller was very active in a large number of scientific societies. In 1907 he was Vice President of Section B of the American Association for the Advancement of Science; in 1914

he was elected to the American Academy of Arts and Sciences; in 1919 to the American Philosophical Society; and he became a member of the National Academy of Sciences in 1921. He was Secretary of the American Physical Society for four years from 1918 to 1922. After this successful term as Secretary he became Vice President in 1923-1924 and President in 1925-1926; and then remained a member of the council for fifteen years. From 1927 to 1930 he was Chairman of the Division of Physical Sciences of the National Research Council. From 1931 to 1933 he was President of the Acoustical Society of America. He maintained an active interest in all of these societies during the rest of his life.

As mentioned earlier, at the age of thirteen Miller purchased his first flute which was one made of silver. From that time to the end of his life he made it a hobby to be interested in flutes of all kinds and made a remarkable collection of them. This collection now numbers 1426 instruments. It also includes a very comprehensive collection of books about the flute and many works of art relating to it. Before his death he made arrangements with the Library of Congress in Washington for placing this collection of flutes on permanent exhibition. In his will he donated this collection to the Library of Congress. The collection was shipped to Washington and it was planned to have the entire exhibit on display by January 1, 1943, but due to the war the exhibit remains in the packing cases and has been transported to a secret place for safe-keeping until after the war.

In addition to the gold flute and the Chinese flutes of jade and carved ivory some of the more interesting specimens in the collection are a glass flute that belonged to President James Madison, a glass flute owned by the Emperor Franz Joseph of Austria, another brought to America by Jerome Bonaparte and a brass flute that was specially constructed for the premiere of the opera Aida at Cairo. Dr. Miller was a consultant for many manufacturers of musical instruments and his researches led to a multitude of improvements.

His industry and conscientiousness made him active in various ways which he considered to the advantage of the community.

As a consequence it is perhaps not surprising that he received the award of the Cleveland Chamber of Commerce in 1928 as the man who had done most for Cleveland in the then current year. That a scientist should receive such an award is perhaps the best of all indications of Miller's personal qualities. His numerous friends and his scientific achievements round out a personality which will be long remembered by scientists.

In this biographical memoir I have borrowed freely from the splendid article written by Dr. Robert S. Shankland entitled "Dayton Clarence Miller: Physics Across Fifty Years," and have borrowed completely the following bibliography which he compiled.

BIBLIOGRAPHY

KEY TO ABBREVIATIONS

Am. Architect—American Architect
Astron. J.—Astronomical Journal
Astrophys. J.—Astrophysical Journal
Bull. Bur. Am. Ethnology, Smithsonian Inst.—Bulletin, Bureau of American Ethnology, Smithsonian Institution
Bull. Natl. Research Coun.—Bulletin, National Research Council
Bull. Polish Med. and Dental Assn. Am.—Bulletin, Polish Medical and Dental Association of America
Central Assn. Sci. & Math. Teachers—Central Association of Science and Mathematics Teachers
Cleveland Med. Gazette—Cleveland Medical Gazette
Elec. World—Electrical World
J. Acous. Soc. Am.—Journal, Acoustical Society of America
J. Am. Chem. Soc.—Journal, American Chemical Society
J. Assn. Eng. Soc.—Journal, Association of Engineering Societies
J. Franklin Inst.—Journal, Franklin Institute
J. Opt. Soc. Am.—Journal, Optical Society of America
J. Roy. Astron. Soc. Canada—Journal, Royal Astronomical Society of Canada
Mod. Sci.—Modern Science
Papers of Am. Musicological Soc.—Papers of the American Musicological Society
Phil. Mag.—Philosophical Magazine
Phys. Rev.—Physical Review
Proc. Am. Acad. Arts and Sci.—Proceedings, American Academy of Arts and Sciences
Proc. A. A. A. S.—Proceedings, American Association for the Advancement of Science
Proc. B. A. A. S.—Proceedings, British Association for the Advancement of Science
Proc. Music Teachers Natl. Assn.—Proceedings, Music Teachers National Association
Proc. Natl. Acad. Sci.—Proceedings, National Academy of Sciences
Proc. Natl. Dental Assn.—Proceedings, National Dental Association
Proc. Royal Soc. Canada—Proceedings, Royal Society of Canada
Proc. S. P. E. E.—Proceedings, Society for the Promotion of Engineering Education
Rev. Mod. Phys.—Review of Modern Physics
Sch. Sci. and Math.—School of Science and Mathematics
Sci. Am.—Scientific American
Sci. Am. Supp.—Scientific American Supplement

Sci. Mo.—Scientific Monthly
Trans. Am. Med. Assn.—Transactions, American Medical Association
Trans. Am. Otological Soc.—Transactions, American Otological Society
Trans. Ky. Acad. Sci.—Transactions, Kentucky Academy of Sciences
Western Reserve Univ. Bull.—Western Reserve University Bulletin

ADDRESSES AND PUBLICATIONS OF DAYTON C. MILLER

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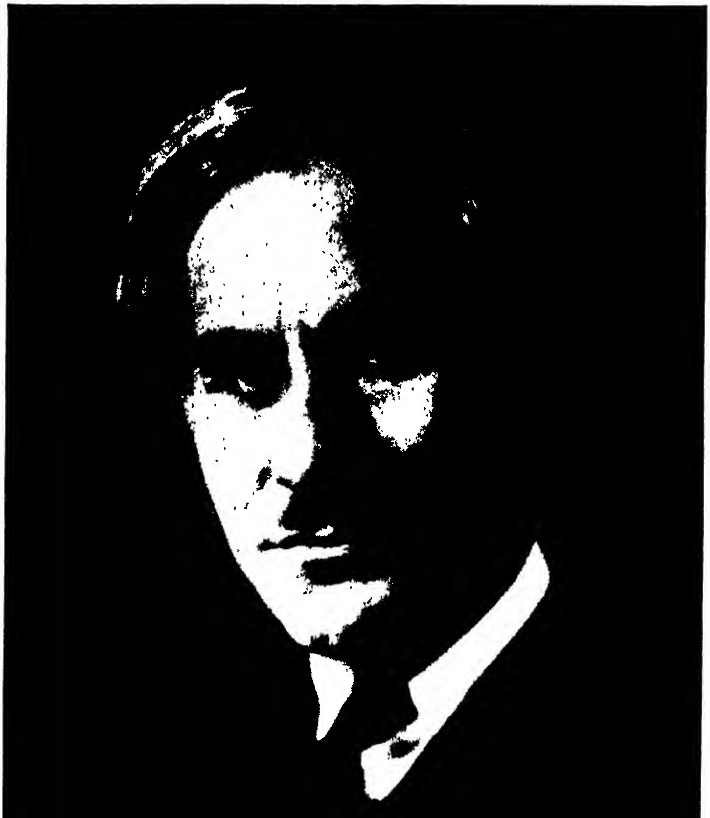

P. A. Levene

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OF

PHOEBUS AARON THEODOR LEVENE

1869–1940

BY

DONALD D. VAN SLYKE
and
WALTER A. JACOBS

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING 1943

PHOEBUS AARON THEODOR LEVENE

1869–1940

BY DONALD D. VAN SLYKE AND WALTER A. JACOBS

Phoebus Aaron Theodor Levene, or Fedya, as he was known to his intimates, was the second of the eight children of Solom and Etta (Brick) Levene. He was born on the twenty-fifth of February, 1869, at Sagor in Russia, and when he was about two years of age his family moved to St. Petersburg, now called Leningrad. He obtained his later schooling at the Classical Gymnasium in St. Petersburg, and finally specialized in medicine at the Imperial Military Medical Academy in that city. He was one of only a few Jewish students who were allowed to enter his class. During his studies there, he was fortunate to have come under the influence of stimulating teachers, and it is of particular interest that among these were Alexander Borodin, the professor of chemistry, but of course now better known as the composer, and Ivan Pavlov, who was at the time a privat dozent in physiology. He studied organic chemistry under Borodin's son-in-law, Professor Alexander Dianin, who was so impressed by the young student that he allowed him the freedom of his laboratory. Here Levene began a first research in organic chemistry on a subject of interest to Dianin, which dealt with the condensation of aldehydes and ketones with phenols. Although he obtained his general training in medicine, it was doubtless during this early period that a strong interest in biochemistry had been awakened. About this time, in 1891, his family, because of growing anti-Semitism in Russia and in order to find broader opportunities and a fuller life, made the decision to migrate to America, and the young Levene accompanied them on the journey. They arrived on July 4, 1891. However, having seen to it that they were safely settled in New York, he returned to St. Petersburg to finish his interrupted studies. But this was temporary for, having once completed his examinations for the medical degree in the autumn of the same year, he decided to try his own fortunes in the New World and thereupon

rejoined his family in New York, which he reached in March 1892. Not long after, he took his examinations for the practice of medicine in New York, and practiced on the lower East Side until 1896. But he was already convinced of the preëminence of his other leanings, and the fortunate decision was made to turn away from the actual practice of medicine as a permanent career as soon as this became possible. While a practitioner, he continued to take time out for further work in physiological chemistry in the laboratory of Prof. John G. Curtis, in the department of physiology of the College of Physicians and Surgeons of Columbia University, which was at that time located on West 59th Street, New York. He had simultaneously enrolled as a special student in the Columbia School of Mines, and absorbed there whatever he felt essential to round out his chemical training. He continued this arrangement for several years, and in an intervening summer recrossed the ocean to spend a short period in the laboratory of E. Drechsel at Berne. In 1896, he received his first appointment as Associate in Physiological Chemistry in the laboratory of the Pathological Institute of the New York State Hospitals, which was housed at the time in the old Metropolitan Life Building, and which was under the direction of Dr. Ira van Gieson. It was while here that an interest was awakened in the subject of the nucleins and nucleic acids which was to become one of his masterpieces.

This earlier period of his work, however, received an abrupt interruption, for in November of the same year he was stricken with tuberculosis. This necessitated a period of rest for about two years. The first of these was spent at Saranac Lake, during which time he gradually regained his health under the care of Dr. E. R. Baldwin. He was well received by the medical fraternity of Saranac Lake, and Levene's charming friendliness and brilliant mind attracted Dr. Trudeau and his associates. The foundations of enduring friendships were then laid which subsequently took Levene on periodic returns, often on vacations, to Saranac Lake, or brought Trudeau and several of his colleagues on visits to him in his laboratory when they came to New York. And in later years it was on one of these trips to Saranac Lake that he found a very great happiness. For in

the fall of 1919, he met Anna M. Erickson, of Lewistown, Montana, who in the following June became his wife.

After his year of rest at Saranac Lake, a succeeding period of cure at Davos, Switzerland, was needed to assure his return to health. Although he was still far from strong, he wished again to pick up the lost threads of his scientific pursuits, and returned to New York. Levene resumed his place at the New York State Pathological Institute, which Dr. van Gieson had held open for him. But not long after, this was interrupted by the closing of the laboratory, pending its reorganization. He then spent a brief period as a visiting worker at Marburg in the laboratory of Kossel, at that time the authority, among other things, on nucleins and nucleic acids. He also enrolled as a visiting student in the electrochemical laboratory of H. Hofer in Munich. Subsequently, at the invitation of Dr. Trudeau, its director, he was induced to accept an appointment as chemist in the Saranac Laboratory for the Study of Tuberculosis. He remained here for the two years from 1900 to 1902, pursuing active research and cementing friendships already begun. His interests by this time had become sharply attracted to proteins and amino acids, and an intervening summer was very profitably spent at the University of Berlin with Emil Fischer. Following a study there on the hydrolysis of gelatine, he returned to New York to resume work in the chemical laboratory of the Pathological Institute of the New York State Hospitals, which had since reopened on Welfare Island (then called Blackwell's Island), and was now under the direction of Dr. Adolf Meyer. He again took up lost threads, and productive laboratory work was continued, accompanied by many contributions to the journals.

It was at this time that the great turning point in Levene's career occurred, and one which proved so fortunate not only for Levene himself, but for American biochemistry. It had come to be realized that research in the laboratory, at least in certain directions in the medical and biological sciences, might find a broader opportunity if given the proper facilities and environment, unhampered by the distractions which can come from administrative or formal didactic routines, not to mention

extramural activities. The Rockefeller Institute for Medical Research was founded at about this time, and Dr. Simon Flexner and his advisers, who planned its organization and scope, realized at the start the importance of biochemistry, and that this discipline would have to share in the activities of the new institution. In seeking for a biological chemist to head its biochemical laboratory, Dr. Flexner had become impressed by the record already made by Levene and by his apparent mastery and appreciation of fundamental biochemical problems, the study of which would fit in with the purposes of such a research institution. He therefore invited the 35-year-old biochemist to join the newly formed organization as an assistant on its scientific staff, an appointment which took effect on January 14th, 1905. This proved to be most fortunate for all concerned. From that time began an association which lasted until his death. From necessarily small beginnings, his opportunities and facilities for work grew with the passing years. When he joined the Institute, its laboratories occupied for a short period temporary quarters consisting of two private dwellings on Lexington Avenue and 50th Street, which had been thrown into one. In the meantime, a new laboratory building was under construction at 66th Street and the East River. In spite of the physical limitations of the temporary laboratory which Levene was given, with only a servant as helper, he threw himself wholeheartedly into the work, and at once initiated the long list of his own share of contributions "From the Laboratories of The Rockefeller Institute for Medical Research," which continued until his death. The success of his activities and the appreciation of his knowledge and experimental genius were so immediate that in the spring of 1907 Levene was made a Member of the Institute, in charge of its Division of Chemistry. Already the recognition which he had achieved was given evidence by the fact that he was among those asked to lecture before the Harvey Society during the very first year of its organization in 1905. The subject of his address was autolysis, and his authoritative treatment of the subject gave immediate evidence of mastery of the historical, as well as factual and theoretical side of biochemistry. During the season of 1905-1906, he was invited also to give the Herter

Lectures in pathological chemistry at the New York University and Bellevue Medical College. He had become a pioneer in biochemical research in its fundamental aspects in this country, as well as a leader of younger men.

On the completion of the new laboratory building in 1906, Levene moved into well-equipped chemical laboratories on its second floor and began work with a few assistants. He continued there until 1918. By this time, the increasing demand of the general Institute activities had made its further physical expansion necessary, and a new laboratory building, the so-called Middle Building of the Institute, was planned which, along with other activities, was to include the Division of Chemistry. In the planning of the new chemical laboratories, Levene was naturally given full opportunity to adapt the benefits of modern improvements in laboratory construction and equipment to the changing requirements of his newer and ever-expanding researches. This was a commission which he undertook with special elation and enthusiasm. Apart from the arrangements in the various laboratories and in the room which was to be his own private workshop, he felt it to be almost as great a responsibility, and found as much personal satisfaction, in the planning of his private office. This became more in the nature of an office library, and no little thought was expended in the selection of its furnishings. This gave opportunity for the expression of the artistic temperament of the man. We remember so well how much experimentation was required for the achievement of the proper shade or tint for the walls and the woodwork. And then in turn these walls and the bookcases were covered, not only with photographs of many of his former assistants, scientific colleagues, and friends, but with reproductions of works of art.

Levene possessed to an unusually great degree this appreciation for art. He took delight in the attempt to analyze not only the technique, but the thought and intent behind the work of the artist. It was undoubtedly from the study of art that he obtained his greatest avocational satisfaction. Because of this, his counsel was frequently sought by those around him in matters

requiring artistic discrimination. In his earlier years, especially when he returned to Europe for so-called vacation periods to work with such leaders as Drechsel, Kossel, and Fischer, he was especially attracted to the work of the Renaissance Schools. He acquired a collection of the works of the older masters in the form of prints or reproductions. In the spring of 1909, following an especially active winter, he sought needed relaxation by a trip to Spain. He came away from there with a new interest in the work of the Spanish schools. He read widely on art and artists, and constantly visited exhibitions of contemporaneous work. His leaning toward the new modes was much in evidence. About 1913, the work of the cubists, which was followed later by the ultramoderns, attracted his attention. The walls of the living room of the Levenes' home and the tops of low bookcases against them were always covered with carefully selected paintings, prints, and other objects of art. The writers recall so well how years ago, when received in an earlier Levene home in West 139th Street, New York, they found themselves in a room where there was but scant wall space between the framed prints of the old masters. In all of this, a great enthusiasm was in evidence, and it was apparent that it was not to be satisfied with half measures, and did not brook restraint. This discriminating taste, along with the gracious kindliness of its hosts, has always made the Levene home a scene of cordial social gatherings to which many scientists, artists, and literary people enjoyed to come.

During his very early professional years, Levene began the accumulation of an exceptional personal library. Although this naturally contained much on art and general literature, the largest portion consisted of scientific books and periodicals which steadily increased with the years. The bound volumes numbered so many that they filled his library at home, shelved from floor to ceiling. In fact, the overflow was such that the shelves stretched into the halls and other rooms. This possession was one of his greatest loves and, of course, a tremendous asset in his work. He was a tireless worker and, although long hours were spent in the laboratory, much was accomplished in the way of

reading, study, or writing at home. This was done at a small desk table in his library, under the light of a floor lamp at its side. On this desk there usually rested an open book with a pad and pencil alongside.

Levene's personal appearance suggested at once the professional man, student, and artist. He was slight of build but wiry, and of dark complexion with deep-set, dark brown, and very frank eyes. In his earlier years his hair was also dark but, as he grew older, it gradually turned to a light grey and he wore it cut rather long. A small mustache and rather heavy eyebrows completed the picture. His clothes, selected with taste and discrimination, conveyed the impression of a well but by no means overdressed man. At his work, he preferred a short, white laboratory coat which reached to his hips.

Because of his brilliant mind, wide reading, and general grasp of problems, many workers, both younger and older, were attracted to him for counsel in professional matters. But also because of his experience, good judgment, and human understanding, they came to him often for advice in regard to their own personal problems. Always of genial and kindly demeanor and with a friendly smile, he listened with an earnest and sympathetic understanding. He was generous, and this generosity reached beyond the demarcations of family ties so that not infrequently there were those who took advantage of an unusually liberal spirit.

Levene was an accomplished linguist. He read voraciously the masters of European literature in their own languages. In addition to his original Russian and the English which he had early mastered, he spoke French and German fluently, and possessed some familiarity with Spanish and Italian. He never lost his Russian accent; although it diminished somewhat with the years, in moments of excitement, such as would come during earnest discussion, it was again more in evidence. His mastery of other tongues served him well in his intercourse with the many foreign visitors who sought him, both in his laboratory and at home. And he was able to guide in their own languages the many foreign students who worked in his laboratory.

Levene was a great teacher, and his mastery of problems as well as of methods for their attack was unusual. He had a very clear way of formulating them. His earnestness, enthusiasm, and courage proved stimulating to his younger co-workers, and he was the obvious master. Although he was very much in his own laboratory or at his desk, a portion of practically every day was devoted to conferences with these younger associates. As a rule, he came to their rooms and engaged in frequent discussions of the problems with them, although in later years such conferences were often held in his office. These discussions were usually long and earnest, and from them new ideas and new points of view emerged which became the starting point of new programs of work. The familiar picture was to see Levene with pencil and paper, poring over problems with the younger man in excited, earnest discussion, and often with a set of molecular models beside them or being manipulated for clearer visualization of some stereochemical question.

When one entered the laboratory where Levene himself was at work, what caught the eye immediately was this small figure of a man surrounded by large pieces of apparatus. There were always a number of operations going on simultaneously and his own and an adjoining room were constantly the scene of active work in which he, the expert manipulator and experimentalist, remained at the controls. Although he naturally had devoted technicians constantly at his side or within call, a great deal was carried on with his own hands, and it was a frequent picture to see this small man shaking a large flask, or pouring from a large precipitation jar into a large Buchner funnel. In the older days when he was preparing the nucleic acids himself from animal tissues, or during his early work in protein chemistry, picric acid was a favorite reagent. Its yellow color was much in evidence throughout the laboratory, and his hands and coat were usually stained with it. He delighted to work himself and felt keenly the desire and responsibility of retaining the "feel" of the operations. Such active laboratory work continued until the very time of his death.

As a rule, especially in later years, Levene spent his lunch period at the desk in his private office where, while mechanically sipping a cup of tea with a light lunch, he read, studied, or wrote. This was followed by a short period of relaxation on a couch, and then he was back in his laboratory, as active as ever. In his work, he was always the enthusiast, and from it he obtained a great personal satisfaction. A restless, untiring energy unconsciously carried him on. A striking quality and one which impressed many who followed him from his earlier days was his unusual capacity to keep pace with, to learn, and to absorb the new as regarded not only the factual side but also the theory and the methodology of his science, and to apply such information to the specific problems which his own fertile imagination formulated. He appeared at home in an ever-changing horizon.

Just as such qualities governed his scientific activities, they similarly determined his avocational pursuits. His moments of relaxation away from his science were occupied with interests which gave him a satisfaction approaching that obtained in his chemical work. Of art we have already spoken. In his later years, he became very much interested in the history of chemistry and read widely on chemists of the past and their influence on the development of the science. Since he was a born student, he always sought to perfect the machinery of his mind by studying other disciplines, such as physics and mathematics. One of his regrets, perhaps, was that he was not a real mathematician, for he began to experience the increasing need for the mathematical analysis and development of certain aspects of the problems in stereochemistry and the Walden rearrangement, which occupied much of the later years of his researches.

Any attempt to present in brief form an adequate picture of Levene's scientific work is made difficult by the fact that his interests grew to include in succession topics of such variety and were so extensive in scope that to cover them would require a long and detailed account. In the span of his scientific activity, which stretched from the work reported in his first paper of 1894 to that to be found in the group of posthumous

papers of 1941, over 700 papers were published. The great majority were original reports of experimental work. Only a minor fraction of the long list consisted of reviews, general articles, and lectures. These he did extremely well, but he seldom took time for them unless pressed to do so. The array of titles, which fall into a number of categories, bears witness at once to the versatility of mind and interests and the tireless energy which made such work in the laboratory possible. The authorship was shared with a long list of younger collaborators who, in the course of years, came to his laboratory for training and stimulation under his guidance. Many of these subsequently gained individual distinction, which they attribute in no small measure to the inspiration they received from him.

Levene appeared on the scene when certain basic problems in biochemistry had come to the fore and were inviting attack. Already the classical researches of Fischer had established the fundamentals of carbohydrate and purine chemistry and had reached the earlier stages of his amino acid and peptide studies. The essential ground work had been laid which could be extended to the investigation of many biochemical problems. Levene was quick to take full advantage of such an opportunity and in succession mastered each of these fields. As we have already related, his original training was in the medical sciences; but he then became a biochemist and, in later years, an accomplished organic chemist who made profitable use also of physical chemistry.

The subjects of Levene's many contributions, while exhibiting, as we have said, an unusually wide range of topics and interests, can nevertheless be grouped according to definitely coherent trends, purposes, and fields. The subjects cover phases of the chemistry of vital mechanisms, and especially the chemical structure and nature of tissue constituents. A list of the fields might be as follows, with no real attempt at a chronological arrangement, since much was simultaneously carried on: autolysis and enzymes; proteins and amino acids; conjugated proteins, such as nucleoproteins and glycoproteins in which, in turn, their prosthetic groups, the nucleic acids and amino sugars or hexo-

samines, became central points of interest. Both the nucleic acids and the hexosamines or conjugated hexosamines required in turn the solution of many problems in sugar chemistry, such as the determination of the ring structures and places of substitution of the sugars and carbohydrate derivatives. The problem of the structure and stereochemistry of the hexosamines especially caused him to undertake extensive investigations into the nature and circumstances of the Walden rearrangement and of the stereochemical configurations of a large number of interrelated synthetic substances. Interspersed in this work was the study of phospho sugars, of phospho hydroxyamino acids, of the sole validity of the peptide chain theory of protein structure as against the possibility of the occurrence of diacipiperazines in the protein make-up. His isolation in 1906 of prolylglycine anhydride among the products of the prolonged tryptic digestion of gelatine was a challenge to the peptide chain theory, which was finally explained only by later work. Systematic and very productive studies in the difficult and laborious field of the lipoids were also carried on under his guidance, or with his own hands. An investigation on the concentration and isolation of the vitamin B complex was also given attention in his laboratory and finally, during the last few years of his life, the chemistry of the gums and pectins attracted his interest.

Levene was a member of many scientific societies, in a number of which election to membership signifies scientific eminence. Other honors came to him, among which was the award of the Willard Gibbs Medal of the Chicago Section of the American Chemical Society in 1931, and of the William H. Nichols Medal of its New York Section in 1938.

Levene presents the picture of an investigator who found a great happiness in the solution of biochemistry's riddles. His constant success was the reason for an innate optimism and a never-diminishing driving force during his lifetime, which developed into a scientific philosophy. This philosophy can be well discerned in the closing paragraphs of his address on "The Revolt of the Biochemists," delivered on the occasion of the

Willard Gibbs Award, in which he refers to the biochemistry of the future:

"Granting that the problem of the directive force (of living matter) will be solved, it may also be granted that the entire mystery of life will not be solved by this achievement. Chemistry, however, is already preparing a new attack. A more essential characteristic of living matter than the directive force of individual chemical reactions is the power to coordinate all chemical reactions in such a way that the organism may function as a whole for the purpose of maintaining its normal equilibrium and for the purpose of growth and reproduction. This may be regarded as the integrating force of the living organism. The discoveries of the last decade alone furnish proof of the simplicity of the agents acting towards this end. Think of all the hormones and vitamins! Only those which as yet have not been isolated may be thought of as complex and mysterious. Those obtained in pure state are most generally found to be much simpler in chemical structure than many of the ordinary tissue components and definitely simpler than certain common drugs. In fact, many of them are nothing more than degradation products of common tissue constituents. Thus, it seems that in the living organism the very wear and tear of the living matter makes for its restitution and for its preservation. A decade is only an infinitesimal interval in the life of mankind and without hesitation or doubt, one may predict that the nature of all hormones and vitamins and other biologically important integrating substances will eventually be discovered.

"Thus, step by step, one mystery of life after another is being revealed. Whether the human mind will ever attain complete and absolute knowledge of and complete mastery of life is not essential. It is certain, however, that the revolt of the biochemist against the idea of a restriction to human curiosity will continue. Biochemistry will continue to function as if all knowledge, even that of life, were accessible to human understanding. The past has taught that the solution of one problem always opens up a new one. New discoveries in physics, in mathematics, in theoretical chemistry furnish new tools to biochemistry, new tools for the solution of old problems and for the creation of new ones. So long as Life continues, the human mind will create mysteries and biochemistry will play a part in their solution."

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1894-1941

The following list of publications of P. A. Levene was very kindly furnished by Mrs. P. A. Levene:

KEY TO ABBREVIATIONS

Am. J. Physiol. = American Journal of Physiology.
Am. Med. = American Medicine.
Ann. Inst. Pasteur = Annales de l'Institut Pasteur.
Arch. Neurol. and Psychopath. = Archives of Neurology and Psychopathology.
Ber. chem. Ges. = Berichte der Deutschen chemischen Gesellschaft.
Biochem. Z. = Biochemische Zeitschrift.
Bull. U. S. Fish Com. = Bulletin, United States Fish Commission.
Centr. Physiol. = Zentralblatt für Physiologie.
Chem. and Ind. = Chemistry and Industry.
Chem. Rev. = Chemical Review.
Chem. Weekbl. = Chemisch Weekblad.
Contrib. Biol. Lab. U. S. Fish Com. = Contributions, Biological Laboratory, United States Fish Commission.
Ergebn. Physiol. = Ergebnisse der Physiologie biologischen Chemie und experimentellen Pharmakologie.
J. Am. Chem. Soc. = Journal, American Chemical Society.
J. Am. Med. Assn. = Journal, American Medical Association.
J. Biol. Chem. = Journal of Biological Chemistry.
J. Chem. Physics = Journal of Chemical Physics.
J. Exp. Med. = Journal of Experimental Medicine.
J. Gen. Physiol. = Journal of General Physiology.
J. Immunol. = Journal of Immunology.
J. Ind. and Eng. Chem. = Journal of Industrial and Engineering Chemistry.
J. Med. Res. = Journal of Medical Research.
J. Mt. Sinai Hosp. = Journal, Mt. Sinai Hospital.
J. Org. Chem. = Journal of Organic Chemistry.
J. Pharmacol. and Exp. Therap. = Journal of Pharmacology and Experimental Therapeutics.
J. Physic. Chem. = Journal of Physical Chemistry.
J. Physiol. = Journal of Physiology.
Med. Klin. = Medizinische Klinik.
Med. News = Medical News.
Med. Rec. = Medical Record.
N. Y. State Hosp. Bull. = New York State Hospital Bulletin.
Proc. Nat. Acad. Sci. = Proceedings, National Academy of Sciences.
Proc. N. Y. Path. Soc. = Proceedings, New York Pathological Society.

Proc. Soc. Exp. Biol. and Med. = Proceedings, Society for Experimental Biology and Medicine.
Z. physiol. Chem. = Zeitschrift für physiologische Chemie.

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$$\begin{array}{c} CH_3 \\ | \\ H\text{–}C\text{–}(CH_2)_nX \\ | \\ R \end{array}$$

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$$(n = O \text{ or } 1;\ R_1 = CH_3 \text{ or } C_2H_5;\ X = OH).$$

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William A. Setchell

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OF

WILLIAM ALBERT SETCHELL

1864–1943

BY

D. H. CAMPBELL

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WILLIAM ALBERT SETCHELL

1864–1943

BY D. H. CAMPBELL

William Albert Setchell was born April 15, 1864 in Norwich, Connecticut, son of George Case Setchell and Mary Ann (Davis) Setchell. His father was a native of Norwich, his mother was born in Trowbridge, England, from which her father, George Washington Davis, moved when she was a small child.

Professor T. H. Goodspeed in his biographical sketch of Professor Setchell[1] says that Dr. Setchell, at an early age showed a strong interest in natural history which later became centered in botany. While a student at the Norwich Free Academy he studied Gray's Lessons in Botany, and spent much time in collecting and studying the flora of the country about Norwich. He made the acquaintance of Mr. George R. Case, deputy collector of Internal Revenue of the Norwich district, and together they undertook the preparation of a local flora to include all plants within a radius of ten miles, to be identified by Gray's Manual. These were to be arranged according to the flowering season. This list of Norwich plants was published in 1883, the year he entered Yale.

At this time Yale had no organized department of botany, although Professor Daniel Cady Eaton, a recognized authority on ferns, was a member of the Yale faculty.

Setchell in the course of his collecting excursions had discovered a fern, *Asplenium montanum,* far west of its hitherto known range. This incident had attracted Eaton's notice and aroused his interest in the young botanist. As there was no special provision in the college for special work in botany, Eaton offered Setchell the privileges of his own library and collections which were in his own house. To quote from Goodspeed's sketch, Setchell wrote "I occupied a table in the

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[1] *William Albert Setchell,* a biographical sketch, University of California Press, Berkeley, 1936.

corner of his (Eaton's) combined library, herbarium and study room, a good library, a good herbarium, a very sympathetic instructor".

It was not remarkable that Setchell's interests, for a long time, were centered in the taxonomic problems in botany. The biological influences which were becoming so potent in some of the botanical work in the western institutions, had not yet reached New Haven.

The last two decades of the 19th century marked a radical change in research and teaching in the biological sciences. This was largely the result of the opening of Johns Hopkins University, and the emphasis on research in the universities where graduates from Johns Hopkins were active.

In botany another equally strong influence was operating from the translation of the great textbook of Julius Sachs, by which most botanists in England and America became acquainted with the work of the great German botanists of the last half of the 19th century. Students became more familiar with the textbooks of Bessey and Coulter, based on the German texts, than with Gray's Manual, and were more interested in morphology and physiology than in taxonomy. During the 80's and 90's many American botanists went to Germany for botanical study especially with Strasburger at Bonn, and Pfeffer at Leipzig.

At the end of his senior year at Yale, Setchell had decided to continue his studies in algae, and through the recommendation of Professor Eaton, and the aid of Professor W. G. Farlow, he received a fellowship at Harvard which provided for study in zoology and botany. Setchell did some work in E. L. Mark's laboratory but his principal interest was his studies of the algae under Farlow's direction. Professor W. G. Farlow had been appointed to the new chair of cryptogamic botany at Harvard on his return from Europe, where he had studied with De Bary at Strasburg and with Bornet and Thuret in France. Farlow did much to advance the study of algae and fungi in the United States, and attracted many students.

Setchell's three years of graduate work with Farlow were of very great value to him in directing his future investigations in algae.

While at Yale Setchell, through Eaton, became acquainted with Mr. Isaac Holden of Bridgeport, an amateur botanist interested in sea-weeds. Setchell joined Holden in collecting the marine algae of the region and later, in association with Frank S. Collins of Malden, Massachusetts, issued a series of dried specimens, which finally reached fifty-one fascicles, under the name *Phycotheca Boreali-Americana* (1895-1919). In the later numbers, Dr. N. L. Gardner, a colleague of Setchell's at Berkeley, was an important contributor.

Gardner took a graduate course at Berkeley under Setchell, received his Ph. D., and later became a member of the faculty and collaborated with Setchell in much of his later work.

At the time Setchell was pursuing his botanical studies at Harvard, there was a number of students, mostly working with Mark, with whom he became associated. Among these were men who later became noted in their professions, including Kingo Miyabe, W. C. Sturgis, G. H. Parker, H. H. Field, C. B. Davenport, H. B. Ward, and C. H. Eigenmann. There were others who were not scientists but whose interest in music, art, and literature was shared by most of the scientific group, and no doubt stimulated Setchell's interest in more general cultural subjects—as might be expected with Boston next door.

Setchell received his Ph. D. in 1890 in biology, and from 1888 to 1891 was assistant to Dr. Farlow. From 1890 to 1895 Setchell acted as instructor at Woods Hole, and continued his researches principally in the Laminariaceae.

While at Harvard Setchell published several papers. The first was a study in the structure and development of a fresh-water alga *Tuomeya fluviatilis,* an important contribution in comparative morphology and his first investigation except in distribution of algae, and taxonomy. His thesis for the Ph. D. was a morphological study but dealt with a kelp *Saccorhiza dermatoidea,* a characteristic species of the northern New Eng-

land coast. He also made a study of a peculiar aquatic fungus *Doassansia.*

A year after receiving the doctorate he was appointed assistant in botany at Yale, and later to an assistant professorship. During this period he became interested in the problems of the distribution of the marine algae, especially kelps. He was especially concerned with the role of temperature, as a primary factor governing their distribution. In 1895 he was called to the University of California as professor of botany and this undoubtedly strongly influenced his future career.

As professor of botany and chairman of the department, he also had the position of botanist to the California Agricultural Experiment Station which later developed into its present great organization at Berkeley and Davis. Under Professor E. L. Greene, his predecessor, the department included Marshall A. Howe, instructor, who later became a member of the staff at the New York Botanical Garden, and a member of the National Academy of Sciences. One of Greene's assistants, W. L. Jepson, still remains in Berkeley as professor emeritus, and an authority on the flora of California.

The transfer of one's home from New England to California involves many changes in one's life, both physical and psychological. Fifty years ago the journey across the continent seemed a much more serious undertaking than it does today. To one who makes this journey for the first time, one's scale of distances undergoes a rapid change. "The West" no longer includes everything beyond the Hudson River, and one learns that Honolulu is a thousand miles nearer to San Francisco than is New Haven.

The Pacific coast is a strange country to one who sees it for the first time. The mild climate, the lofty mountains, and the rugged coast and huge waves are a great contrast to most of the Atlantic coast. The vast evergreen forests clothing the mountains are very different from the forests of the East.

To the botanist California is known as one of the richest floral regions in the world, and Setchell must soon have realized the immense new field opened to him in the Pacific sea-weeds,

some of which, like the giant kelps, attract the attention of the most casual tourist. The climate too, gives the botanist an uninterrupted twelve months for his out-of-door studies.

Moreover, all the lands of the vast Pacific area are accessible directly from San Francisco, and after the three thousand mile journey across the continent, one looks ahead to possible visits to some of these fascinating places. Although California has been politically American for nearly a century, geographically it really is nearer to Mexico, to which it formerly belonged, than to the eastern United States; and there are still many evidences of the Spanish era.

The University of California was founded in 1868, but although it had on its faculty men of recognized standings like John and Joseph La Conte, Hilgard, and others, the college remained small, and was little known outside California. There were several small sectarian colleges, like Santa Clara College, but these offered little competition with the State University.

In 1891 Stanford University opened with Dr. David Starr Jordon as president. Jordon, as president of the University of Indiana, had been successful in reorganizing that college and was already known as an energetic reformer in educational affairs; and Senator Stanford selected him to head the university founded as a memorial to his only son.

The establishment of another university in the Bay Region was not too warmly welcomed at Berkeley, but the new university undoubtedly did stimulate the activities of the State University. In 1899, with the appointment of Benjamin Ide Wheeler as president, a new era began at Berkeley and the State University started its extraordinary development which carried it to its present brilliant position in the front rank of the nation's great universities.

At the beginning of Wheeler's regime, Setchell was active in the organization of the university as a member of various committees, administrative and academic.

Goodspeed writes "He was one of those who interpreted the academic atmosphere of Harvard and Yale in terms of western ideals. He was both official and unofficial advisor to members

of the student body, and their appreciation was expressed in his early election to membership in their honor societies".

In 1895 when Setchell reached California, Berkeley was a small town on the eastern shore of the bay opposite San Francisco. In many ways Berkeley resembled the small college towns in New England and elsewhere. There were several men in the faculty, both from Yale and Harvard, and Setchell probably soon adjusted himself to his new environment.

However, looking across the bay, and reached by a short ferry trip, one could see San Francisco and the Golden Gate, opening into the Pacific and to all the wonder lands of that vast ocean.

Fifty years ago, San Francisco was the only major city in the United States west of the Mississippi, and the recognized metropolis of the whole region west of the Rocky Mountains. Throughout the Pacific coast it was "The City", with a very marked atmosphere of its own, and its superb location and picturesque social life made it unique among the country's cities.

The cosmopolitan population and sensational history were unequalled by any other American city, except possibly New Orleans. The European element in the population was large, and many prominent citizens were of French, Italian, Spanish, or German origin, and the numerous Chinese added a distinct flavor of the Orient. The many foreign restaurants were also a feature of the city, which in many ways was more like a Continental city than like the typical American ones.

Many of its leading citizens were graduates of famous universities, American and European, and there was a general appreciation of music and art. From the days of Mark Twain and Bret Harte there were many capable writers and painters, some of whom became famous. The city was accustomed to the visits of all the world-famous actors and musicians, who were always liberally patronized.

From an early period there was a marked interest in scientific activities, and in the early 50's the California Academy of Sciences was established and became the most important center of scientific activity on the Pacific coast. A legacy from James

Lick, who also endowed the Lick Observatory, enabled the Academy to provide a building, and support a considerable staff of scientific workers, and funds for the publication in excellent form of the results of their investigations.

There was a competent staff of botanists and a valuable herbarium, and the Academy was the principal center of botanical work in the state. Setchell undoubtedly found the resources of the Academy of great help in his early days at Berkeley. The president of the Academy at that time was Dr. H. W. Harkness, well known for his studies in a curious group of subterranean ("hypogaeous") fungi, (truffles and related forms). Setchell met Harkness, and became interested in his work.

Setchell's interests in San Francisco were not restricted to fungi. He was by no means unaware of the many attractions of the city, aside from its scientific advantages, and it is not unlikely that these at times may have diverted him from his strictly professional interests.

Setchell's first year at Berkeley was evidently a very busy one, as shown by the list of his publications for 1896. He published several papers in the Laminariaceae (kelps) in which he was always much interested. There are many extraordinary genera of these big brown algae peculiar to the Pacific coast. In 1897 he published a textbook, *Laboratory Practice for Beginners in Botany*. Among his most important investigations were studies of the factors determining the distribution of the Laminariaceae.

The immediately following years seem to have been less productive, but in 1899 he made his first trip to Alaska, and made extensive collections. He described the algae of the Pribilof Islands in President Jordon's report on the fur-seal islands of the Alaska region.

In 1903, in collaboration with Dr. N. L. Gardner, was issued by the University of California Press, the first volume of Algae of Northwestern America, which must be ranked as Setchell's most important contribution to American botany. The last volume of this important work appeared in 1925.

In 1920, Setchell was engaged by the Carnegie Institution of Washington to conduct certain investigations in the Samoan Islands. This first visit to the South Seas had a marked influence upon his future work and he developed a strong interest in the biological problems of the southern Pacific, especially the distribution of insular floras both marine and terrestrial, coral reef formations, especially the role of Coralline algae, in reef building, and various problems concerned with plant distribution. As director of the botanical garden of the university, he made a collection of the commercial varieties of tobacco, and other species of *Nicotiana,* grown from seed from many sources. These showed much uncertainty as to nomenclature. Continued experiments resulted in the establishment of a collection of stable and correctly named species and varieties. Setchell spent much time in studying the results of hybridizing these forms of *Nicotiana,* and the cytogenetics of the genus *Nicotiana* was carried on later by Goodspeed and R. E. Clansen of the university.

Setchell's numerous collecting trips began in 1896, his first year in California. With Dr. W. L. Jepson, then an assistant in the department, he made a wagon trip from Berkeley to the Santa Cruz Mountains on the coast south of San Francisco, and then to the San Joaquin Valley and the Yosemite. Collections were made of the vascular plants, fungi, and fresh-water algae. Two years later he visited Yellowstone Park, and made a special study of the thermal algae. In 1900 he spent the summer in Hawaii. Three years later, on sabbatical leave, he made a round-the-world trip, visiting important herbaria in Europe, and later visiting Egypt, India, and New Zealand, and collecting material, especially marine and thermal algae. He visited Europe later for further study of types of algae in the most important herbaria.

In 1920 Dr. Setchell married Mrs. Clara B. Caldwell, of Providence, and during the next twelve years made several extensive journeys on which his wife accompanied him and was associated with him in his botanical investigations. These journeys included visits to many islands of Polynesia—Hawaii,

Samoa, Tahiti, Fiji—also New Zealand, Australia, including the Great Barrier Reef, South Africa and Java. The great collections of material accumulated from these extensive journeys were, of course, of enormous value in his investigations. Mrs. Setchell evidently made a favorable impression on Setchell's associates at Berkeley, and she took an active interest in his work, both at home and when traveling. "She assisted her husband in the organization and classification of his library, notes, and collections, and later having perfected herself in microtechnique, in the researches which he had in progress." [2] She died several years before her husband, but he himself was an invalid for several years before he died.

Setchell's investigations made in Samoa on his first trip, for the Carnegie Institution, developed a new interest in the biological problems relating to the marine algae, and these problems became an important feature in his subsequent expeditions to most of the important South Sea Islands, as well as Australia and New Zealand, South Africa and Japan.

He thus collected algae in all these regions, and his first-hand knowledge of the algae of most of the Pacific area was probably unequalled by any other student of these important organisms.

In these extensive travels he became acquainted with the land floras, as well, and some of the problems connected with their distribution. The great importance of his work was recognized by his colleagues everywhere. His explanation of the factors dealing with the distribution of the kelps and his demonstration of the important role of the coralline algae as reef-builders are examples.

The recognition of his standing as a botanist was shown by his election to membership in all the leading American scientific societies, and also in many foreign ones.

Setchell died in Berkeley, April 5, 1943, ten days before his seventy-ninth birthday.

[2] Goodspeed, *loc. cit.*

SPECIES OF PLANTS NAMED FOR PROFESSOR WILLIAM ALBERT SETCHELL

Algae

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(Prepared by T. H. Goodspeed and Lee Bonar)

KEY TO ABBREVIATIONS

Am. Anthrop. = American Anthropologist.
Am. Jour. Bot. = American Journal of Botany.

Am. Nat. = American Naturalist.
Ann. Bot. = Annals of Botany.
Ann. Mo. Bot. Gard. = Annals, Missouri Botanical Garden.
Ann. Rept. Marine Biol. Lab., Wood's Hole, Mass. = Annual Report, Marine Biological Laboratory, Wood's Hole, Massachusetts.
Ber. Deuts. Bot. Ges. = Berichte der Deutsche botanischen gesellschaft.
Biog. Mem. Nat. Acad. Sci. = Biographical Memoirs, National Academy of Sciences.
Bot. Gaz. = Botanical Gazette.
B. P. Bishop Mus. Bull. = Bernice Pauahi Bishop Museum, Bulletin.
B. P. Bishop Mus. Occas. Pa. = Bernice Pauahi Bishop Museum Occasional Papers.
Bull. Soc. Botanique = Bulletin, Societe botanique de France.
Bull. Torr. Bot. Club = Bulletin, Torrey Botanical Club.
Carneg. Inst. Wash. Pub. = Carnegie Institution of Washington Publications.
Compt. Rend. Somm. Séances Soc. Biogéogr. = Compte rendus Sommaire des seánces Societe de biogéographie, Paris.
Det. Kgl. Danske Videikeb. = Det Kongelige danske videnakabbemes.
Fern Bull. = Fern Bulletin.
Flora Mid. Calif. = Flora of Middle California.
Hong Kong Nat. = Hong Kong Naturalist.
Inst. Alg. Res. Hokkaido Imp. Univ. = Institute of Algological Research, Hokkaido Imperial University.
Johns Hopk. Univ. Circ. = Johns Hopkins University Circular.
Jour. Mycol. = Journal of Mycology.
Jour. Wash. Acad. Sci. = Journal, Washington Academy of Sciences.
Just. Bot. Jahresbr. = Just's Botanischer Jahresbericht.
Mem. Nat. Acad. Sci. = Memoirs, National Academy of Sciences.
Mid-Pacific Mag. = Mid-Pacific Magazine.
Monog. des Oscill. = Monographie des Oscillariées (Nostocacées Homocystées) Paris, 1893.
Proc. Am. Acad. Arts and Sci. = Proceedings, American Academy of Arts and Sciences.
Proc. Am. Philos. Soc. = Proceedings, American Philosophical Society.
Proc. Biol. Soc. Wash. = Proceedings, Biological Society of Washington.
Proc. Calif. Acad. Sci. = Proceedings, California Academy of Sciences.
Proc. Linn. Soc. N. S. W. = Proceedings, Linnean Society of New South Wales.
Proc. Nat. Acad. Sci. = Proceedings, National Academy of Sciences.
Proc. 3d Pan-Pac. Sci. Congr., Tokyo = Proceedings, Third Pan-Pacific Scientific Congress, Tokyo.
Proc. 4th Pac. Sci. Congr., Java = Proceedings, Fourth Pacific Scientific Congress, Java.

Proc. 5th Pac. Sci. Congr., Victoria and Vancouver = Proceedings, Fifth Pacific Scientific Congress, Victoria and Vancouver.
Records, Am. Soc. Nat. = Records, American Society of Naturalists.
Rept. Nov. Spec. = Repertorium novarum specierum regni vegetabilis.
Rept. Work Agr. Exp. Sta., Univ. Calif. = Report, on Work of the Agricultural Experiment Station, University of California.
Rev. Algologique = Revue Algologique.
Rev. Sudam. Bot. = Revista sudamericana de botanica.
Rev. Syst. Surv. Melobesiae = Revised systematical survey of the Melobesieae (Norske videnskabers-selskab. Skrifter, 1900).
Siboga Exped. Mon. = Siboga-expeditie Monographie.
Sierra Club Bull. = Sierra Club Bulletin.
Trans. Conn. Acad. = Transactions, Connecticut Academy of Arts and Sciences.
U. C. Agr. Exp. Sta. Circ. = University of California Agricultural Experiment Station Circular.
U. C. Pub. Bot. = University of California Publications, Botany.
Univ. Arskkr. N. F. = Lund Universitet Arsskrift.
Univ. Chron. Berkeley = University of California Chronicle.
Year Book Carneg. Inst. Wash. = Yearbook, Carnegie Institution of Washington.

1883

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ROSS AIKEN GORTNER

1885–1942

BY

SAMUEL COLVILLE LIND

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1943

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1885–1942

BY SAMUEL COLVILLE LIND

Ross Aiken Gortner was born on his father's farm ten miles north of Ewing, Nebraska, March 20, 1885. George Gortner, his great great grandfather, was of Pennsylvania Dutch stock and was said to be the first white man to settle in Lycoming County, Pennsylvania, where he was killed by the Indians in 1778. Ross' father and mother, with their daughter, Lide Edith, a baby of only a few months, left Pennsylvania in 1868 and joined the western migration, settling in Hampshire, Illinois. Here two sons, Harley Dewitt and John Narver, were born, but Harley died in infancy. The pioneer spirit still persisted, and in 1882 the family moved farther west in a covered wagon and settled in Nebraska, where they homesteaded. At the time of Gortner's birth, his father was active as a Methodist minister. In this capacity he rode circuit each week, preaching Friday night, Saturday night, three times on Sunday, and Monday night. Most of the farm work devolved upon the mother, while the father was away on the circuit of sixty miles, which he covered part of the time on horseback and part in a two-wheeled cart.

This family life represented typical American pioneering of that period. According to Gortner's own statement, he was born "in a sod house". At the time it was built in 1883, it was the only sod house in that section of the country which could boast both a wooden floor and two windows with glass. It was looked upon in the neighborhood as an exceedingly luxurious abode. Later a frame house was built on the homestead which the family occupied.

When he reached the age of two and a half years, his father finished "proving up" on the homestead and enlisted as a Methodist missionary to go to Africa, taking with him his family consisting of his wife, young Gortner, and an older brother. They sailed in the fall of 1887 for "Garraway Station" approximately thirty miles up the coast west of Cape Palmas, Liberia. The

location of the station proved to be extremely unhealthy and later came to be known as "The white man's grave." After a few months his father and mother were stricken with "African fever", probably either malaria or yellow fever. His father died early in March 1888 while his mother was unconscious and the older brother so ill as to be unable to walk. His father was buried near the mission house in a rude casket made by tearing down a partition of the house. The family fell temporarily to the care of a Christian native during which period there was a gap of approximately six weeks in the family recollection. When his mother had recovered sufficiently to inquire about her son, no one knew where he was until he was found in the native village a mile from the mission where he had adopted the life of the native children and having learned to speak Kru fluently had more or less forgotten English. As soon as his mother was well enough, she returned with the two boys to the United States and rented a farmhouse in Holt County, Nebraska. The sod house in which he was born had been torn down for the lumber which it contained.

When Gortner was five years of age, the family moved to Evanston, Illinois, so that his brother, who was eleven years older, might study for the ministry, while he started in kindergarten. After he had finished the first grade in the public schools at Evanston, his brother became very ill and the family moved back to the homestead for a year's recuperation following which the family moved to Inman, Nebraska, where his brother had a pastorate for two years, then at Newman's Grove, Nebraska, for two years, and later at Osmond, Nebraska. Gortner attended public school at all of these places. Certainly his youthful education was very irregular and much interrupted.

When Gortner was in his early teens, his mother became very ill. They moved back to the homestead while she was completely bedridden. Gortner then did all of the housework and took complete care of his mother who gradually improved. He attended the country school terms during this period though not during the first year after their return to the homestead. When he was fourteen years old his mother realized the inadequacy of the rural schooling and following his father's

last wish "give the boys an education," he and his mother moved to Neligh, where he entered the seventh grade. They remained there three years by which time he completed the ninth grade. His mother then sold the homestead and purchased a house at University Place, Nebraska, close to the Nebraska Wesleyan University. Here he entered the preparatory school in the fall of 1902 which was closely affiliated with the college, so that he was able to take college work together with preparatory subjects for the Bachelor of Science degree which he received in June 1907. He thus completed three years of preparatory work and four years of college in a five-year period carrying as much as 25 credit hours most of the time. During the first three years of this time, his mother was almost entirely a bedridden invalid, and again the entire housework and her complete care fell upon him. He states there were three weeks at a time when he did not take his clothes off except for a bath or to change them, sleeping on a cot drawn across the door of his mother's room so that he could be at her side when needed. His lessons were prepared in the evening after the housework was done. Washing, bread baking, etc., were finished before he left for a 7:15 class. He had no time for outside activities and during the last two years of his mother's life, spent every evening at home. She died in June 1905 of pernicious anemia. This account of Gortner's early life and schooling reminds one of Abraham Lincoln's early life. Both illustrate typical pioneering spirit. Gortner was also a great reader. While there was no public library in the smaller towns and villages of Nebraska at that time, fortunately his father had left a rather extensive private library, and although many of these books were ecclesiastical, nevertheless, Gortner believed that he had read everything in his father's library with the exception of Caesar's Commentaries in Latin, which he tried to read, picking out one word at a time from the Latin dictionary, but finally gave it us as a hopeless task. Apparently Gortner never had any systematic training either in Latin or Greek.

Partly on account of defective eyesight, first recognized after he entered college and partly because of his mother's invalid-

ism, he was unable to enter into any of the usual boy's sports. He took his recreation in reading instead of play.

Evidently Gortner's preliminary education was obtained under the greatest difficulties, all of which he overcame by his will to accomplish and his unflagging enthusiasm which marked him throughout his later life.

Gortner's description of his first coming under the influence of Professor F. J. Alway with whom he was closely associated later at the University of Minnesota, and his choice of the field of chemistry is quoted as follows: "I had no particular objective in mind at the time I entered the Academy of Nebraska Wesleyan University. In this small school registration was carried out with all of the faculty assembled in the library, each student going to each specific faculty member to ask for permission to register for specific courses. When I matriculated in the fall of 1902, I had a hazy idea that chemistry might be interesting and approached Professor F. J. Alway and asked him what chemistry was like. I shall never forget how he looked up at me, smiled and replied, 'If you stick at it long enough, some day you will be able to do something that no one ever did before.' Then and there I resolved to try to be a chemist."

Even in his undergraduate career, Gortner developed a taste for research and published two papers giving the results of experimental investigations within three years after he came to know Dr. Alway. During his undergraduate years, Gortner gradually worked up to be one of the recognized assistants in chemistry. In return for his services, he received free tuition and laboratory fees. His duties consisted of the care of the stockroom, and, as he says, "the winding up of the windlass which lifted the large drum of rock which in turn acted as a weight and operated the gasoline-gas machine which provided gas for the laboratories." Even under these conditions, all of the assistants were encouraged to carry on research. In 1904 Gortner had his first introduction to organic chemistry. In 1905 his second research paper was published jointly with Dr. Alway in the *Berichte der deutschen chemischen Geschellschaft,* 38: 1899-1901 (May, 1905). He

was so thrilled by the logic of the science of organic chemistry that he resolved to become an organic chemist. During the year 1905-06 he worked practically all of the organic syntheses in Gattermann's "Practical Methods of Organic Chemistry."

He went with Dr. Alway to the Nebraska Agricultural Experiment Station in the fall of 1906 as research assistant, a half-time position that paid fifteen dollars a month. In the remaining half-time, he completed the work for the Bachelor of Science degree at Nebraska Wesleyan University.

Upon graduation he was appointed to a scholarship at the University of California, but resigned to accept the position as assistant in chemistry at the University of Toronto where he worked under the late Dr. W. Lash Miller during 1907-08, and received the Master of Arts degree in June 1908. During his stay with Lash Miller, he gained a training in the field of physical chemistry which stood him in good stead for the rest of his career. In the spring of 1908 he applied for and received appointment as University Fellow at Columbia University where he took a major in organic chemistry under Professor Marston T. Bogert, a minor in physical chemistry under Professor J. Livingston Morgan, and biological chemistry under professor W. J. Gies. He thus rounded out his training both in the field of organic and of physical chemistry and had an unusual preparation to combine the two in his future studies and in their application, including colloid chemistry, to the problems of biological chemistry. During the summers of 1907-08-09 he held full-time positions as research assistant under Dr. Alway at the Nebraska Agricultural Experiment Station. He received his doctorate in June 1909 at Columbia. Shortly before completion of his work he was recommended for a position in the Station for Experimental Evolution of the Carnegie Institution of Washington at Cold Spring Harbor, Long Island, in spite of the fact, as he says, that he never had a formal lecture in biological chemistry. He accepted the position and began work at Cold Spring Harbor on September 1, 1909. He states that he never told Dr. Davenport why he could not begin earlier, but the fact was that he wished to get hold of a good text of biological chemistry and find out what the

subject was about. Besides this preoccupation, he also acted in the summer of 1909 as research assistant with Dr. Alway and read biological chemistry in the evening. He married Catherine Victoria Willis, of Dorchester, Nebraska, on August 4th.

Gortner remained five years in a research capacity in the Carnegie Institution at Cold Spring Harbor. All of his associates were biologists. In the beginning he knew little or no biology. These five years, therefore, gave him an invaluable postgraduate training in that field. During this period he first became associated with Dr. J. Arthur Harris. He also valued highly his associations with Dr. A. M. Banta, Dr. C. B. Davenport, Dr. H. D. Goodale, and Dr. A. F. Blakeslee. Gortner states that this period of association at Cold Spring Harbor made up for much of the inadequacies in his undergraduate preparation. He soon came to realize that his future interest would lie in the field of biological chemistry rather than in synthetic organic chemistry.

Late in 1914 he was offered an associate professorship of soils at the University of Minnesota where Dr. Alway had gone as head of the Division of Soils, a position which he held until his retirement in 1942. Dr. Harris strongly urged that he accept, believing that it would be an advantage for him to come in contact with student thought, which opportunity was not available at Cold Spring Harbor. He entered his new duties on August 1, 1914, and remained for two years as Associate Professor in the Division of Soils. During this time he became associated with Professor R. W. Thatcher who was Chief of the Division of Agricultural Biochemistry. Later with Dr. Alway's consent, Dr. Gortner transferred to that division. A year later Dr. Thatcher was made Director of the Department of Agriculture at the University of Minnesota and Gortner was promoted to a full professorship and was made Chief of the Division of Agricultural Biochemistry which position he held until his death in 1942.

Gortner states that at the time when he became Chief of the Division of Agricultural Biochemistry in August 1917, the University of Minnesota was just emerging from the status of one of a number of state universities to one of the larger

of the American universities. The graduate school was just beginning. It developed subsequently under the leadership of Guy Stanton Ford as Dean of the Graduate School who became Acting President in 1937, and President in 1938. The first doctorate in biochemistry was conferred in June 1915. In the early days of the Graduate School nearly all of the students were subsidized by assistantships or fellowships which was also true of graduate students in agricultural biochemistry. Later Gortner attracted more and more graduate students from all over the world. In 1927 a special building was constructed on the Agricultural College campus to house agricultural biochemistry. It was planned to accommodate thirty-five graduate students. Before Gortner's death more than twice this number had to be accommodated to take care of those who came to him from all parts of the world.

Besides his unusually good training for the field to which he contributed so much, Gortner bore a personal spirit of enthusiasm and a universal interest for scientific knowledge and research which was in my opinion the real secret of his great success. He was a great teacher. His students were devoted to him and he was devoted to his students. He collected about him a very able staff of associates in carrying on the work of his division. He maintained a personal library and a reprint file which was open to all of his students and which provided a most valuable center of research facilities.

One of Gortner's most outstanding contributions to the field of biochemistry was his "Outlines of Biochemistry," a work of about 1,000 pages, the first edition of which appeared in 1929, the second in 1938. In his treatment he cut loose from any restrictions of specialization or application and gave himself widest range over the entire realm of biochemistry. Here he could bring to bear his remarkable knowledge of organic, physical, colloidal and physiological chemistry to produce a remarkable treatise useful alike to all specialists in the fields of biology, physiology and medicine.

The book was received with universal approval. Professor Wilder D. Bancroft stated in his review in the Journal of Physical Chemistry, "It is a pleasure to come across a book

occasionally, which is written because the man knows his subject."

The British Medical Journal stated:

"Professor Gortner's book presents, as no other single book has done, a measure of the contribution of organic and of physical chemistry to the problems of vital processes. . . . It is the book of biological chemistry. . . . The general biological outlook of the book has permitted the assembly of a great deal of valuable material not elsewhere collected in one place. The author exercises wise discretion in the presentation of theories and in the balancing of conflicting views. The text is liberally annotated with references to the original literature. This book may be strongly recommended to students in all branches of pure or applied biochemistry."

William Seifritz, in his review in Science, stated:

"The success of the application of physics and chemistry to biology depends upon two conditions: first, the ability of the biologist to master physics and chemistry and yet remain a biologist, and second, the willingness of the physicist and the chemist to cooperate sympathetically with the biologist. Professor Ross Aiken Gortner is an outstanding example of the fulfilment of the first condition. In reading his 'Outlines of Biochemistry,' it would be difficult to say whether Professor Gortner is biologist or chemist. He speaks to both in their own language, an attribute which few possess."

The last section of his "Outlines" is entitled "The Biocatalysts," which in the first edition included only the vitamins and the enzymes. In the second edition a chapter on hormones is added and that on vitamins greatly extended by addition of the new discoveries of their chemical composition and synthesis.

Probably no field of chemistry will change more in the next hundred years than biochemistry. But Gortner's "Outlines" will remain a landmark recording accurately its status and greatest progress in 1938.

His chemical library and his reprint files were presented to the University of Minnesota and will be retained in his institute for agricultural biochemistry. The collection of reprints will be known as the "Gortner Collection of Separates." This together with a similar collection presented to the Uni-

versity by the late Professor Herbert Freundlich, constitute a most valuable collection of literature in the field of colloids and biochemistry. At Gortner's request certain of his files of journals, such as are already represented in the University library, will be presented later to "a reconstructed Chinese university." His chemical library was donated by his sons, Dr. Ross Aiken Gortner, Jr., and Dr. Willis Alway Gortner. The collection of separates was bequeathed by will to the University of Minnesota.

Although Dr. Gortner never worked in a European laboratory, nor even visited Europe, he developed a research organization with all the spirit and charcteristics of the best European institutes. He was well known to all the leaders in colloid chemistry and biochemistry in the world. Those of them who visited Minnesota, expressed highest appreciation of his contributions and eagerly sought him out for personal contact.

Many honors came to Dr. Gortner during his long and productive career. He was Wisconsin Alumni Foundation Lecturer in 1930, Priestly Lecturer at Pennsylvania State College in 1934, and George Fisher Baker Lecturer at Cornell University for the fall semester of the academic year 1935-36. The Cornell lectures were published in a volume entitled, "Selected Topics in Colloid Chemistry." The honorary degree of Doctor of Science was conferred on him by Lawrence College in 1932. He was president of the American Society of Naturalists in 1932, president of Sigma Xi in 1941, and president of Phi Lamda Upsilon from 1921-26. He served on several committees of the National Research Council, and in 1942 was awarded the Thomas Burr Osborne Medal by the Association of Cereal Chemists. Upon the recommendation of the division of chemistry, Gortner was elected a member of the National Academy of Sciences in April, 1935.

On August 1, 1942, he completed twenty-five years as Chief of the Division of Agricultural Biochemistry. A testimonial dinner had been planned for October 2, 1942, at which he was to have been presented with a bound volume of more than two hundred letters from his former associates, colleagues, and

graduate students. Instead of this happy celebration, fate made it the day of his funeral. He never saw the volume, but it remains as a testimonial of affection and regard of all of those who had worked with him.

In his research and teaching, Gortner adopted and steadfastly held to the principle that if the fundamental phenomena are known and understood, the technological application can be made with greater exactness and certainty.

The number and variety of Dr. Gortner's scientific contributions, more than 300, attests to his wide research interests. The papers may be grouped into about a dozen major fields to which most of his work was directed. They include a study of melanin, the chemistry of embryonic growth, physicochemical properties of vegetable saps, the humin fraction in protein hydrolysates, the organic matter of soil, the chemical and colloidal properties of flour proteins, sulfur in proteins, physicochemical studies on proteins, electrokinetics of colloidal systems, interfacial energy and the molecular structure of organic compounds, the role of water in living processes, the chemistry of wood and of the pulping process. At the time of his death he was engaged in a joint research with Dr. Alway on a comprehensive study of the sulfur metabolism of plants. So varied were his interests that his influence was felt in the research of almost every field of agricultural science.

At the same time, however, that he conducted his researches with so much ability and distinction, he was active in many of the more general interests of the University. He served on many important committees in the Department of Agriculture and in the University. At an early date he became chairman of the Graduate Group Committee for Agriculture in the Graduate School. In this capacity he rendered invaluable service to Dean Ford who perhaps had a more thorough appreciation of his gifted service than anyone else not professionally associated with him.

He also found time to interest himself in such subjects as secondary education. This was brought more forcibly to his attention by the fact that he had two sons and two daughters, who were educated in the public schools of Minne-

sota before entering the University. He acted as chairman of a committee of the American Chemical Society to collect data in the State of Minnesota on the training and preparation of teachers of chemistry in the public schools. His interest in this subject was unabated until his untimely death. Both of Gortner's sons, Ross Aiken, Jr., and Willis Alway have chosen scientific careers. Ross Aiken Gortner, Jr., after taking his Ph.D. degree at the University of Michigan, holds a position as Assistant Professor at Wesleyan University, Middletown, Connecticut, but is now detailed for war service in Washington on the Food and Nutrition Board of the National Research Council. The second son, Willis, who received his Ph.D. from the University of Rochester in 1940, is an Assistant Professor in the School of Nutrition, Cornell University, Ithaca, New York.

His daughters Elora Gortner Page and Alice Gortner Johnson are both married and live in St. Paul. There are seven grandchildren in the four families. All four of Gortner's children were by his first wife who died in March 1930. In 1931 he married Rachel Rude who had served him for many years as secretary. This union proved most suitable and happy, blessing his later years particularly after he was seriously stricken with coronary thrombosis.

The summer of 1938 was spent by Gortner, his wife, and daughter Alice in Hawaii where Gortner served as consultant to the Sugar Planters Experiment Station of which Dr. Harold Lyons was director. Here he renewed an acquaintanceship of long standing with Dr. Royal Chapman who later became Dean of the Graduate School of the University of Minnesota, which position he held until his death. While in Hawaii Gortner was first stricken with what he failed to recognize as a very serious heart attack. He misjudged it to be indigestion and thought to overcome it by such outdoor exercise as swimming, mountain climbing, and deep-sea fishing. He later told me that he regarded it as a most fortunate circumstance that a large, deep-sea fish which he had hooked managed to break away after a struggle of a half an hour. Had he been compelled to hang on much longer for the capture he believed he might

have lost his life on that occasion. It was not until he returned to Minneapolis in the fall of 1938, that his ailment was diagnosed as coronary thrombosis. The peak of the attack had already passed, probably while he was in Hawaii. His condition was found to be quite serious. He was never given any great hope of long survival. After several months of complete rest he was able to return to partial duties and gradually recovered to a point where he again directed the research activities of his laboratory and performed all of his usual daytime duties. He realized that his days were numbered. A few months before his death he told me that he thought he might go on for several years or he might go off suddenly at any moment. He never let this thought disturb him. He proceeded with his daily duties and kept up all his activities with enthusiasm unabated. He died almost literally in the harness, as he had wished. The end came suddenly on September 30, 1942, after he had been forced by one or two severe attacks to be hospitalized for a few days. Thus came to an untimely close a life devoted to science with all the energy and enthusiasm with which it was so richly endowed.

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KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

Amer. Chem. Jour. = American Chemical Journal
Amer. Jour. Bot. = American Journal of Botany
Amer. Jour. Physiol. = American Journal of Physiology
Amer. Nat. = American Naturalist
Amer. Sci. = American Scientist
Ann. Int. Med. = Annals of Internal Medicine
Ann. Rev. Biochem. = Annual Review of Biochemistry
Ber. deut. chem. Ges. = Berichte der deutschen chemischen Geschellschaft
Biochem. Bull. = Biochemical Bulletin
Biol. Abstr. = Biological Abstracts
Biol. Bull. = Biological Bulletin
Bot. Gaz. = Botanical Gazette
Bull. Soc. Chim. (France) = Bulletin Société chimique de France
Bull. Torrey Bot. Club = Bulletin, Torrey Botanical Club
Cereal Chem. = Cereal Chemistry
Chem. Bull. = Chemical Bulletin
Chem. Met. Eng. = Chemical and Metallurgical Engineering
Ind. Eng. Chem. = Industrial and Engineering Chemistry
Jour. Agr. Res. = Journal of Agricultural Research
Jour. Amer. Chem. Soc. = Journal, American Chemical Society
Jour. Amer. Med. Assoc. = Journal, American Medical Association
Jour. Amer. Soc. Agronomy = Journal, American Society of Agronomy
Jour. Biol. Chem. = Journal of Biological Chemistry
Jour. Chem. Educ. = Journal of Chemical Education
Jour. Dairy Sci. = Journal of Dairy Science
Jour. Exper. Zool. = Journal of Experimental Zoology
Jour. Gen. Physiol. = Journal of General Physiology
Jour. Home Economics = Journal of Home Economics
Jour. Ind. Eng. Chem. = Journal of Industrial and Engineering Chemistry
Jour. London Chem. Soc. = Journal, London Chemical Society
Jour. Organic Chem. = Journal of Organic Chemistry
Jour. Phys. Chem. = Journal of Physical Chemistry
Ohio Nat. = Ohio Naturalist
Physiol. Res. = Physiological Researches
Phys. Rev. = Physical Review
Proc. Nat. Acad. Sci. = Proceedings, National Academy of Sciences
Proc. Soc. Exper. Biol. Med. = Proceedings, Society for Experimental Biology and Medicine
Proc. U. S. Nat. Mus. = Proceedings, United States National Museum
Rev. Sci. Instr. = Review of Scientific Instruments
School and Soc. = School and Society

Sci. Mo. = Scientific Monthly
Trans. Chem. Soc. (London) = Transactions, Chemical Society of London
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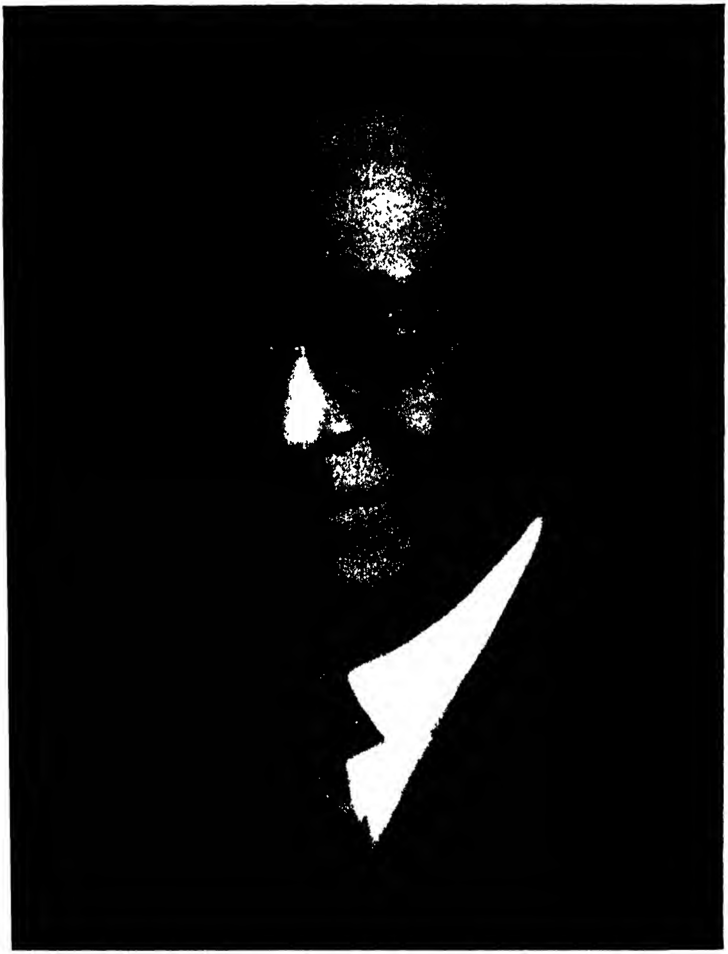
EDITORIAL POSITIONS

At various times, R. A. Gortner has served as associate editor of the Journal of the American Chemical Society, of the Journal of Physical Chemistry, and for a long period of years as assistant editor of Chemical Abstracts.



Joseph S. Ames

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OF

JOSEPH SWEETMAN AMES

1864–1943

BY

HENRY CREW

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1944

JOSEPH SWEETMAN AMES

1864–1943

BY HENRY CREW

There are times when a single act characterizes the entire life of a man. Such an occasion was the publication of his first scientific paper by Joseph S. Ames. He had just taken his bachelor's degree at Johns Hopkins University; was an assistant in the laboratory and was, at the same time, working toward a doctor's degree. On his way to those experimental results which later formed his doctor's dissertation, he had met for the first time the then recently invented concave grating. This remarkable instrument he mastered, in theory and in practice, so completely that he was invited by its inventor to describe, for the leading journal of physics, its construction, adjustment and use. This he did with such accuracy, clarity and completeness that this first paper soon became and remained, on both sides of the Atlantic, the standard guide for the Rowland mounting.

The outstanding features of this paper (*Phil. Mag. 27,* 369, 1889) are simplicity, logical sequence, accuracy, fine perspective; and these are also the outstanding features of Ames' life.

Two great English poets have taught us that the child is father to the man; a dictum which every man who has lived through two generations has verified for himself. It is therefore well worthwhile to follow the rather meagre record of this man's ancestry in order to discover, if possible, among his forebears and friends—for these latter are often one's most important ancestors—the origin of some of those qualities so highly cherished by men who knew him.

From the rather scanty data which Dr. Ames deposited with this Academy in 1926, one learns that both of his paternal grandparents were born in Vermont, while the maternal pair

came from the neighboring state of New York. The genealogy of the family is briefly set forth in following table:

Benjamin Ames of East Dorset, Vt. b. 1798—d. 1866	married	Lydia Griffith of Danby, Vt. b. 1804—d. 1866

and had a son,
George L. Ames,
who lived in Manchester, Vt.
b. 1832—d. 1869.

Nathaniel Bacon of Ballston Spa, N. Y. b. 1802—d. 1869	married	Jane S. Sweetman of Charlton, N. Y. b. 1801—d. 1841

and had a daughter,
Elizabeth L. Bacon,
who lived in Manchester, Vt.
later in Niles, Mich. and in
Faribault, Minn.
b. 1836—d. 1921.

In 1859, George L. Ames married Elizabeth L. Bacon. Their only child, Joseph Sweetman Ames, was born in Manchester, Vermont, on July 3, 1864.

The fact that his grandfather Ames was known "for his fair-mindedness," that he possessed an excellent library, and was a man of scholarly tastes, allows us no reason for surprise at the scholarly instincts of the grandson.

Still less are we surprised when we learn that his grandfather Bacon, a graduate of Union College, was a lawyer, judge and farmer, "devoted to travel and legal studies." Ames' mastery of clear and forcible English may not be unrelated to his grandmother Bacon's "marked literary ability." The father, Dr. George L. Ames, found his favorite study along the lines of botany and entomology: but was "a great reader, especially in history and biography and had an exceptionally good library." Having completed the course at the Louisville Medical School he began the practice of medicine at Niles, Michigan. His death in 1869 brought an irreparable loss to his young son. The lad, however, was fortunate in having an able mother, a woman who had inherited from her own mother definite literary tastes and was devoted to poetry; so that the boy was brought

up, as he says, "in an environment of books and among well educated people."

As indicating the manner in which the twig was bent, witness the following from his autobiographical memoranda:

"My father died when I was four years old and my only recollections of the period before I went to boarding school are those of ordinary boyish games. I remember, however, that when I was about twelve years old I was asked by a cousin what I was going to be when I grew up, and I replied 'A teacher of Mathematics!' This subject always appealed to me, and when I was eight years old, I could do such operations as square roots."

In 1872, the eight-year-old boy was sent to the Shattuck School in Faribault, Minn., because his mother was very favorably impressed with the personality of Bishop Whipple, who lived in Faribault and who was an outstanding pioneer in the Episcopal Church as well as one of the founders of the Shattuck School.

Two years later, in 1874, Mrs. Ames married the Rector of the school, Dr. James Dobbin, a graduate of Union College. A result was that here, in the invigorating atmosphere of southern Minnesota, and among its glacial hills, the young Ames spent the next nine years of his life. Here also he had all the social advantages (and disadvantages) of being at once in school and at home. Here too he had the privilege of training in a school which still respected the fundamentals. Here by a thorough study of the two basic languages of western civilization—the languages of Homer and Virgil—he acquired a rare mastery of clear and accurate English. The Shattuck Catalogue for 1866-7 shows that "The course of study covers six years, with Latin and Mathematics in each year, Greek and English in each year but one, and French and German each for two years." A footnote explains that "Declamations and compositions are required throughout the course." The present headmaster of the Shattuck School, Mr. Nuba A. Pletcher, writes me that on the walls of the building is a record of "the scholastic leaders of the school through all the years." "In that list," he says, "Joseph Ames stands as first boy of the school in 1879, '80, '81, '82, '83."

His friends of that period report him as "very reserved," "very smart," "knew all that was going on," was good company and possessed of a fine sense of humor. "In school," says Ames, "I was especially interested in Mathematics, Latin and Greek." It is easy to believe that these studies are to some extent responsible for the logical acumen and the fine sequence of thought so constantly exhibited during all his later life.

Just how the attention of this young man was first directed to Johns Hopkins University is not entirely clear; but there is good reason to believe that the initial incentive came from the following paragraph in a magazine article which fell under his eye in 1880. The writer of this article, in describing Johns Hopkins University and emphasizing its devotion to pure research, said: "It possesses no history, claims no distinguished sons, has, indeed, hardly reached the dignity of *alma mater*." In any event, Ames tells us very distinctly how, when once there, he entered upon the pursuit of physics. Following is one of the few paragraphs in his brief autobiographical memorandum:

> "My reason for starting in with Physics when I came to the Johns Hopkins University was because I realized that here was an entirely new field of investigation and study, to which I had had no approach in school. I determined, therefore, to simply look at Physics as a part of a general education, but I soon became so interested in it and in the mathematical side of it that I determined to pursue it definitely."

As an undergraduate at Baltimore, he maintained the same reserve, the same quiet dignity, the same military bearing which had characterized his school life at Faribault. No student who sat in the same class with him ever failed to acquire a high respect for his native ability and quick wit. In conversation he was direct and incisive; candid with every one; confidential with none; an excellent listener withal. The dignified manner in which he wrestled with and conquered an impediment of speech heightened the regard of all his fellow students and, later, of his colleagues. A large part of all his undergraduate work—such, for example, as chemistry, hydrodynamics and

differential equations—was done in courses where the majority of the students were graduates of other institutions.

Along in the seventies and eighties of the last century, the custom of study in a foreign university had become so popular among graduate students in America that it was a veritable

J. S. AMES, STUDENT AT THE UNIVERSITY OF BERLIN, 1887.

craze. The fashion had been initiated by men such as B. A. Gould, Harvard '44, and Basil Gildersleeve, Princeton '49, who, at Göttingen and at Bonn, had left an honorable and long-lived tradition of American scholarship. At the time when Ames matriculated, there was, indeed, a "Johns Hopkins University Club" to which the sole requirement for admission was that the applicant had previously studied in some foreign university.

One evening in the spring of 1885 Ames, as a guest of the present writer, attended a *Kneipe* of this club, a highly amusing affair, where the program included the reading of a *Bier-zeitung,* the drinking of a *Bier-duell* and various songs from the *Kommers-buch.* The prestige of the German university was already beginning to decline; but the dominant fashion had affected Ames much in the same manner as the rest of us. He wanted his foreign experience to be first hand. Accordingly, in the following summer, immediately after his graduation, he and the writer of this sketch took passage on the steamship *Anchoria,* a twelve-day boat of the Anchor Line. The ship was not more than two days out of New York when Ames knew all the more interesting men and women on the passenger list. Passionately fond of society, he was never a mere recipient; but always a contributor to any group in which he found himself. As a traveling companion, he was remarkable. Stepping off the train at Glasgow, Edinburgh, London or Paris, he had already mastered his Baedeker in such a thorough and characteristic fashion that he was instantly at home. This geographic familiarity never ceased to amaze his fellow traveler, who on a previous trip had acquired it only at considerable expense of time and energy. A short while in Paris was spent on French conversation.

At the end of the summer, Ames went, *via* Switzerland, to the University of Berlin where he spent the remainder of the academic year. Working in Helmholtz's laboratory, he there met those two kindred spirits, Arthur Gordon Webster and Michael I. Pupin. No three men ever possessed more distinct personalities than these; and yet they had in common a versatility, a largeness of heart, a breadth of view, and a respect for the unglossed facts which made them fast friends as long as they lived. The tradition of this trio lingered in Berlin much as that of Gould and Gildersleeve in Göttingen and Bonn. As one can imagine, Ames was, during this winter in Berlin, exactly in his element. For, in this well policed and orderly city, there were approximately five hundred American girls; some traveling with their families, some there for music, others for art, and all

learning the German language. His correspondence during this period shows how thoroughly Ames enjoyed swapping conversation with these young people.

Never fascinated by German methods, Ames returned to Baltimore in the summer of 1887; proceeded to do three excellent pieces of work in spectroscopy; and took his doctor's degree in 1890. From 1888 to 1891, he held an assistantship in Rowland's laboratory; and in 1891, he was invited to occupy the associate-professorship left vacant by the migration of Professor A. L. Kimball to Amherst College. Ames thus became the second man in the department and one upon whom Rowland relied and trusted absolutely, his *alter ego,* in fact. Promotion to a full professorship came in 1899. This chair he held for twenty-seven years, yielding it only to accept the provostship of the University in 1926.

Following the early and lamented death of Professor Rowland in 1901, Ames was, with the widest approval, chosen to succeed him as Director of the Physical Laboratory. These first eleven years after taking his doctor's degree were full of work; and by the turn of the century he had established his reputation as an inspiring teacher and as an expositor of the first order. During this same period, while Rowland was creating the modern science of spectroscopy, Ames was giving an elementary course in general physics [represented by his *Theory of Physics,* Harpers, 1897] and also a more advanced one, known as the Major Course, besides handling much of the administrative work of the department. It was in this same period that, on invitation of Dr. George E. Hale, he joined the editorial staff of *Astrophysical Journal.*

His interest in the history of physics awakened about this time, and led him to undertake the supervision of *Harpers Scientific Memoirs,* a series of twelve volumes in which are reprinted, with expository and biographical notes, a large number of fundamental researches in modern (not recent) physics. Four of these volumes were edited by Ames himself. Along this same historical and critical line is a paper on "The Mechanical Equivalent of Heat" which he presented to the *Congrès International*

de Physique (Paris: 1900.) Here, within some thirty pages, he gives an admirable appraisal of the methods employed and the results obtained by the best experimentalists up to the date of the congress. While not a skilful manipulator himself, Ames had surprising familiarity with the best that had been done and said in the laboratory. Accordingly he joined with his late colleague, Professor W. J. A. Bliss, in the production of *A Manual of Experiments in Physics* (American Book Co. 1896), an authoritative and widely used guide to sound laboratory practice.

As one might well expect, Ames was, along with Webster and Pupin, one of the prime movers, charter-members and, later president of the American Physical Society which was launched in New York City in the spring of 1899.

To this last decade of the nineteenth century belongs also one of the happiest events of Dr. Ames' entire life. For it was in the early nineties that he had the good fortune to meet, in a purely social way, Mrs. Mary B. Harrison, *née* Williams, at the home of Colonel David G. McIntosh in Towson, Maryland. She was the mother of three children; had been a widow for several years; was an excellent *raconteuse* and strikingly handsome. In her were combined all those fine qualities which we associate with good ancestry, with the old South, and with a keen sense of responsibility. They were married in St. Marks Church at Pikesville in 1899. The home which they built in Guilford, a mile or two north of the University, soon came to be, and ever remained, a happy spot for the entire family. One of his closest friends, Dr. J. B. Whitehead, a former student and a long-time colleague of Dr. Ames, writes: "I think that his married life and home atmosphere were to him the greatest things in his career; and that he fled to them for refuge often in a life which seems to me to have been even more of a struggle for him than for most of us." The desolation and loneliness which came with the death of Mrs. Ames in 1931, he bore with characteristic courage.

As indicated above, the first period of Dr. Ames' work covers the last decade of the nineteenth century. The second

period extends over the first quarter of the twentieth century and covers his teaching career. Following the death of Professor Rowland in 1901, the departmental strength was gradually increased by the appointment of such productive scholars as Dr. R. W. Wood, Dr. J. B. Whitehead, Dr. A. H. Pfund, Dr. J. C. Hubbard, Dr. K. F. Herzfeld and others.

Superposed upon teaching duties were numerous public addresses. Notably one on Relativity. Others were the course of Harris Lectures given at Northwestern University in February of 1913. These six popular addresses upon *The Constitution of Matter* (Houghton, Mifflin & Co.; 1913) were based largely upon the ideas of Sir J. J. Thomson concerning atomic structure and those of H. A. Lorentz concerning electrons. Delivered, as they were, upon the eve of Bohr's great work, they represent the utmost reach of human effort in solving the mysterious structure of matter *without the idea of the quantum and without the nucleus of Rutherford.* Eleven years later, from the same platform and upon the same topic, he gave a lecture—fascinating in its clarity—dealing with the enormous strides recently made in atomic structure.

The fairest appraisal of a teacher is probably that given by the top men in his classes. The following accurate pen-portrait of Ames, the teacher, was kindly written for this sketch by Dr. Richard T. Cox, one of his ablest students.

"Among Dr. Ames' qualities as a teacher probably the first to impress a student was the great respect in which he held science, especially his own science of physics. This respect combined with his native dignity to give his lecture room an air of some austerity. In his experimental demonstrations he avoided the spectacular; for students, he said, remember only the spectacle and forget the principle. To some young students who laughed at the odd gyrations of a piece of apparatus he said gravely, 'I may be deficient in humor, but I have never seen anything laughable in the laws of nature.' In the same way, in his expositions he avoided every show of cleverness and paradox. The laws of nature were to be understood not by being clever but by using Common Sense, words which he always pronounced as though he were at the same time writing them in capitals. Perhaps it was also a gesture of his respect

for physics that he kept to the old-fashioned custom of lecturing in a cutaway coat, even though he might have only a single student in a class.

"If this trait impressed itself first upon a student mainly by such singularities as these, and if perhaps some noticed these gestures and nothing more, to those who were his students for several years the impression became clearer and deeper and probably remained as their most lasting recollection of Dr. Ames. For it became plain to them that his respect for science was an attitude of spirit far transcending any outward sign. It was evident in his custom of never referring to himself as a physicist but, even when he was eminent in the profession, calling himself still a student of physics. It was clear also in the disdain in which he held the commercialization of science, though in its use for real human welfare he was always interested.

"He prepared his lectures with the greatest care and, although he gave the same cycle of courses for many years, he rewrote his notes in detail each time. But he never looked at a note while lecturing, and he discouraged his students from taking notes in the lecture room, for he wanted them to think rather than take dictation. Although he was himself a man of incisive mind and strong character, he did not expect his students to conform to any pattern of his own or any other. He kept himself free from narrowness, recognized the various talents and handicaps of others, and tried to help each to make the best of what abilities he had. When he talked with his students outside the lecture room, he dropped the greater part of his gravity, encouraged those who were depressed, and listened with good nature to those who were cocksure.

"He had a very wide and accurate knowledge of the literature of physics, and the number of researches of which he remembered the author and the year and place of publication was always a matter of wonder. The contribution he made to research in sharing this knowledge can not be calculated, but they deserve to be remembered. At length, however, the changes in physics were so many and came so fast that he decided he could no longer keep up with them. To others he seemed to be keeping up very well, but he acted on his own judgment. When he gave up his professorship, he called in all of his students and former students and distributed his whole physical library among them. So, generously and without complaint, he ended in his own way his years as a teacher of physics."

In the midst of the second period of Ames' career came the First World War. American intervention brought with it a

two-fold demand upon American men of science. One was to learn of the work already done in various fields bearing upon the war; the other was to offer France and England all possible assistance from our laboratories and scientific workers. It was with these ends in mind that Dr. Ames was invited, by the National Research Council, to head its Scientific Mission to France and England in the spring of 1917. Other members of the commission were Dr. George A. Hulett of Princeton, Dr. George K. Burgess of the Bureau of Standards, Dr. Harry F. Reid of Johns Hopkins, Dr. Richard P. Strong of Harvard and Dr. Linsly R. Williams of New York. The story of the mission and its results are charmingly told, by the leader, in the *Johns Hopkins Alumni Magazine* for November, 1917. A close friend and colleague, who lived and worked with Ames for forty years, Dr. J. B. Whitehead, writes that

". . . the background materials for his programme [in aeronautics] were acquired by his visits to England and France in World War I. He had intimate conferences with authoritative bodies and individuals in both countries, and I have been told that his report upon his return dwelt particularly upon those features of fighting planes which needed study and correction."

The appointment of Dr. Ames to be Provost of the University brought to a close this second period of his work in 1926. But this shift of emphasis was not allowed to interfere with an important joint undertaking with Professor F. D. Murnaghan. The volume on *Theoretical Mechanics* (Ginn & Co.) which these two gentlemen published in 1929 deals with the oldest branch of physics and with one which is fundamental to all the experimental sciences. Yet they treat it with such novelty, clarity and logical consistency as to give it place among the already classical works of Lagrange, Poisson, Thomson and Tait, Kirchhoff and Webster.

It was in this same year, 1929, that Ames had thrust upon him the difficult and uninviting presidency of an impecunious university, at the very moment when the nation was entering upon its deepest financial depression. Fortunately loyalty to his *alma mater* and to his own ideals gave him courage which knew

no limits. He was as ardent as was President Gilman in his advocacy of the early ideals of the university when men counted most, when methods and technique were secondary. The following paragraph is from a letter of congratulation which he received in June of 1929 from a fellow professor in another university:

"You are strong enough not to become drunken (as a smaller man might do) with the great power placed in your hands. Your sense of fairness and justice is so keen that you will always have the loyalty of your faculty. Your judgment is so sound that the trustees will not attempt to steer the ship from some point behind your back."

How well this prediction was fulfilled and how well his administrative duties were performed may be judged, perhaps, from an address presented him by his colleagues in 1933 when he completed his 50th year at the university. The last paragraph of their brief message reads as follows:

"In your progress from freshman to fellow, from professor to president—an office which it has been your lot to fill in most trying times—you have won and held from your colleagues in all departments, that respect and affectionate regard that prompts them now to wish you many more years of health and happiness and the continued enjoyment of the interests with which these past fifty years have been enriched."

Close friends and colleagues will recognize the following sentences from Professor George Boas as an accurate and penetrating appraisal of Ames as a university president:

"Among his outstanding qualities was a *great intuitive sense of human character.* He would sweep away all rules and regulations for the benefit of a man whose character he trusted. Bibliographies, national reputation, etc., were nil if the man in question was narrow-minded, uncultivated or ungentlemanly. He had no use for pedants, for people with bad manners or for bigots.

"His office door was always open to the youngest and newest member of the faculty as well as to the most famous and oldest. He had a healthy but imprudent contempt for his trustees and the alumni, which was of no help in raising money. In extenuation, it must be admitted that he received from his

trustees utterly inadequate support, (moral as well as financial). One outstanding reform was his abolition of professional athletics."

One who wishes to see the other side of the shield can find it in the perfectly frank after-dinner address which Dr. Ames gave before the American Association of University Professors at Duke University in December of 1929. He was speaking on the functions of trustees, president and faculty, and said:

"As to the trustees it is their absolute duty to accept any recommendation that comes to them from the faculty when proposed by the president. I don't see how any university can exist if this policy is not adhered to. . . . As for the president, his primary duty without any exception is to uphold the faculty. . . . I refer to tenure of office, freedom of speech, morale, all that goes to make up a faculty. This is his primary duty. . . . The primary purpose in life of a professor is to conduct his own investigations and lead his own scholarly life, and the more attention he can pay to that, the better it is for an institution."

If one recalls that evening in the spring of 1875, when Mr. Gilman, the newly chosen president of Johns Hopkins University, had just met the young Rowland of Troy and was strolling with him along the edge of the cliff at West Point, and presently offering him a professorship in the university about-to-be at Baltimore; if one recalls this event, I say, he will be interested in remembering also that, at that moment, the eleven-year-old lad in Shattuck School, out in Minnesota, was in the next twenty-five years to succeed Rowland in his chair of physics and at the end of another twenty-five years to succeed Gilman in the presidency of the University. Even more remarkable is the fact that, in each case, Ames was the conservator of his predecessor's ideals.

The retirement of President Ames was the outstanding feature of the Commencement Exercises, held in the Lyric Theater on the afternoon of June 11, 1935. His address to the graduating class upon *Freedom of Thought* was followed by a congratulatory address from the Board of Trustees. In this manner came to an end the third period in the life of this unselfish, straightforward, friend of every honest scholar.

Never since the early experiments of Langley in aerodynamics and the actual flight of the Wright brothers in 1903 has there been any doubt, in the minds of intelligent men, concerning the important rôle of the airplane either in civil life or in warfare. It was on the 3rd of March 1915, that the Congress of the United States established, as a war measure, the National Advisory Committee for Aeronautics. Dr. Ames was one of the original members. The Committee has always included a distinguished group of scholars such as Admiral D. W. Taylor, Professor W. F. Durand, Dr. George K. Burgess, Admiral William A. Moffet, Mr. Orville Wright, Mr. Charles A. Lindbergh, Dr. S. W. Stratton, Dr. C. D. Walcott, Dr. George W. Lewis, Professor Michael I. Pupin, and Professor W. C. Sabine.

No more authoritative account of Dr. Ames' aeronautical work can probably be found than the following minute adopted by this eminent committee on January 26, 1943, and kindly furnished to the present writer by Dr. W. F. Durand:

"During the twenty-four years which he served on the National Advisory Committee for Aeronautics, Dr. Ames probably contributed more than any other man to the development of the science of aeronautics in this country. One of the original members of the NACA appointed in 1915 by President Wilson, Dr. Ames served as Chairman of the Executive Committee of the NACA from 1919 to 1936, as Chairman of the main committee from 1927 to 1939, and at different times on more than twenty of its subcommittees. The patriotic and generous public-minded spirit with which Dr. Ames made his numerous contributions to the Committee is brought out by the fact that he served all these years without pay.

"The fact that few people know of Dr. Ames' many achievements and contributions is attributable to the quiet and modest way in which he conducted both his own affairs and those of the NACA. The success of his 'All Work and No Talk' policy, however, has not escaped the attention of the outstanding leaders of aeronautical science. Few men before their death have been so deservedly honored as was Dr. Ames. Shortly after his resignation as Chairman of the NACA in 1939, because of failing health, Dr. Ames was informed that the new NACA $16,000,600 aeronautical research laboratory at Moffet Field, California, was to be named the 'Ames Aeronautical Laboratory' in his honor. This laboratory, the second aeronauti-

cal research station of the NACA, now plays a vital role in the world-wide struggle for qualitative supremacy in aircraft.

. . . "Members of the Air Commands of the Army and Navy placed great faith in Dr. Ames and followed his inspiring leadership in the prosecution of aeronautical research directed to keeping America ahead of other nations in the design of airplanes. Among the signers of a testimonial resolution adopted at the October 19, 1939, meeting of the NACA, recognizing the great work of Dr. Ames were the following responsible chiefs of military aeronautics: Lt. General Henry H. Arnold, now Commanding General of the Army Air Forces; Lt. General George H. Brett, formerly Chief of Air Operations in the Southwest Pacific under General MacArthur and now Army air commander in the Caribbean area; and Vice Admiral John H. Towers, formerly chief of the Navy Bureau of Aeronautics and now Chief of Air Operations in the Pacific. This resolution stated:

" 'For over twenty years Dr. Ames has served as chairman of the National Advisory Committee for Aeronautics or as Chairman of its Executive Committee. His long service leaves upon the organization the indelible imprint of his character. He is not only a great scientist, he is a great man, and we are proud to have been associated with him.

" 'When aeronautical science was struggling to discover its fundamentals, his was the vision that saw the need for novel research facilities and for organized and sustained prosecution of scientific laboratory research. His was the professional courage that led the Committee along new scientific paths to important discoveries and contributions to progress that have placed the United States in the forefront of progressive nations in the development of aeronautics. His was the executive ability and farsighted policy of public service that, without seeking credit for himself or for the Committee, developed a research organization that holds the confidence of the governmental and industrial agencies concerned and commands the respect of the world. Withal Dr. Ames was an inspiring leader of men and a man beloved by all his colleagues because of his rare personal qualities.'

"Dr. Ames' scientific knowledge and professional attainments are exemplified by the fact for many years he was an outstanding physicist on the faculty of Johns Hopkins University and for the latter part of his career served as president of that great educational institution.

"Other public honors have come to Dr. Ames in spite of his

unassuming and modest ways. In 1923 he was invited to present the Wilbur Wright Memorial Lecture before the Royal Aeronautical Society of Great Britain.

"In 1935 he was presented the Langley Gold Medal for Aerodromics by Mr. Chief Justice Charles Evans Hughes, then Chancellor of the Smithsonian Institution, in recognition of the 'surpassing improvement of the performance, efficiency, and safety of American aircraft resulting from fundamental scientific research by the National Advisory Committee for Aeronautics under the leadership of Dr. Ames.'

"Much credit for the many outstanding accomplishments of the NACA must also be given to Dr. Ames, for it was under his courageous leadership that the foundation for the progress in airplane design now being realized was laid. In 1930 the NACA was awarded, by President Hoover, the Collier Trophy for having made, during the previous year, 'the greatest achievement in aviation' in the development of the NACA cowling.

"A glance at a group of modern airplanes on almost any American airport would bring into view many features developed by the Committee under the guidance of Dr. Ames. The famous NACA cowling for radial air-cooled engines, the NACA low-drag wing, the proper location of engines and nacelles in the wing of an airplane, the size and location of the control surfaces, the tricycle landing gear, and the general streamlining and contour of the modern airplane represent results of work done in the laboratories of the Committee.

"With the nation now involved in a global war in which air power is a dominant factor, the work done by Dr. Ames in improving the efficiency and performance of our aircraft over a period of more than twenty years is of inestimable value to his country."

It was in 1939, four years after retiring from the presidency of the University, that Dr. Ames resigned the chairmanship of the NACA. Only two years earlier he had suffered a stroke of paralysis which confined him to his home for the remainder of his days. This disaster he met unflinchingly, as indeed he had every other crisis of his life.

"His courage and high spirit" says his close friend, Dr. J. B. Whitehead, "were never seen more clearly than during his last illness when he was nearly helpless for months. I saw him often and he was always cheerful; although his progress was steadily downward, he always reported his condition as 'fair'."

His death came on Thursday, June 24, 1943. The funeral services—full Requiem Mass—were held on the following Saturday at the Mt. Calvary Protestant Episcopal Church in Baltimore—the church of which he was a vestryman. The burial was in St. Thomas Churchyard in Garrison Forest, near Pikesville, Maryland.

Much more important than any single piece of work was the influence which Dr. Ames exerted, through his warm human spirit and his high aims, upon his students, his colleagues, and all who learned to know him.

KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

Amer. Jour. Chem. = American Journal of Chemistry.
Astrophys. Jour. = Astrophysical Journal.
Astron. and Astrophys. = Astronomy and Astrophysics.
Conserv. Rev. = Conservative Review.
Johns Hopkins Alumni Mag. = Johns Hopkins Alumni Magazine.
Johns Hopkins Univ. Cir. = Johns Hopkins University Circular.
Jour. Franklin Inst. = Journal, Franklin Institute.
Jour. Roy. Aero. Soc. = Journal, Royal Aeronautical Society.
N. A. C. A. = National Advisory Committee for Aeronautics.
New Ped. = The New Pedagogue.
Phil. Mag. = Philosophical Magazine.
School Sci. and Math. = School Science and Mathematics.
Trans. Amer. Inst. Min. Met. Eng. = Transactions, American Institute of Mining and Metallurgical Engineers.

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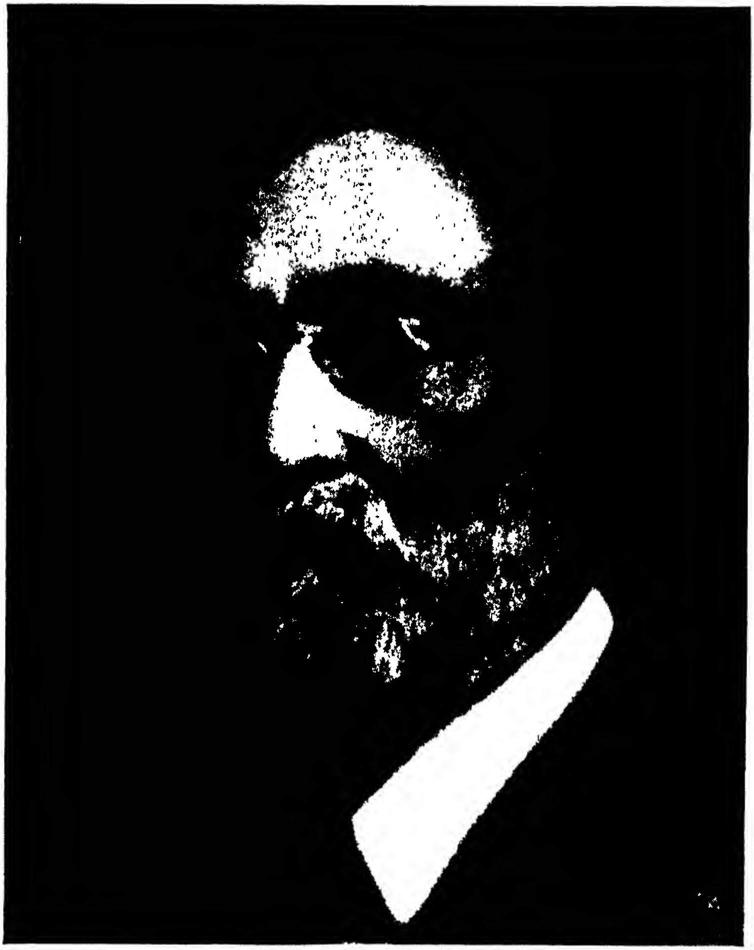

Frank Leverett.

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OF

FRANK LEVERETT

1859–1943

BY

WILLIAM H. HOBBS

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1944

FRANK LEVERETT

1859–1943

BY WILLIAM H. HOBBS

The greatest American glacial geologist of our generation and one of the greatest of all time died after a brief illness at his home in Ann Arbor, Mich., November 15, 1943. He was born March 10, 1859 in the little village of Denmark in the extreme southeastern corner of Iowa.[1] Denmark had been founded only twenty-two years earlier by pioneer farmers from New Hampshire and Massachusetts. They came with traditions of culture and they were largely Congregationalists in their religious faith. With little delay they had founded Denmark Academy and the first Congregationalist church west of the Mississippi River. The Academy prepared its students for college, and schooling and religion bulked large in the village life.

Frank Leverett's nearer ancestors included college graduates, and he was probably descended in the ninth generation from Thomas Leverett, who emigrated from Boston, England, to Boston, New England, in 1663. Frank's descent is through Major General Sir John Leverett, son of Thomas, an early governor of the Massachusetts Bay Colony, and through John Leverett, son of Sir John, the eighth president of Harvard College.

The nearest ancestors of Leverett were mainly pioneer farmers from Maine and New Hampshire, strong and enduring and of outstanding longevity. So far back as the record is available it is as follows: Frank 84, father 79, mother 70, paternal grandfather 74, paternal grandmother 81, maternal grandfather 87, maternal grandmother 82, maternal great-grandfather 87, his father 87 and mother 96, his grandfather 93 and grandmother

[1] In 1895 Dr. Leverett submitted to the National Academy of Sciences an autobiographical sketch of five manuscript pages together with a list complete to that time of his published work. This list was supplemented by one covering his later papers. This was mailed August 2, 1943, a few months only before his death. The sketch has been used in preparing this memorial and the bibliography has been printed without change.

96. The average age of these eleven successive immediate ancestors including Frank himself is more than 84 years.

Leverett entered Denmark Academy with no plan of later going to college, but expecting to be a farmer as was his father. He completed the academic course in 1878 when nineteen years of age. He was then interested in stock raising, horticulture and scientific agriculture. He taught school for two years, but in 1880, when he became of age, an interest in scientific lines was stimulated by an uncle, Colonel G. B. Brackett, who was a prominent horticulturist later to serve for some years as chief pomologist of the United States Department of Agriculture. Frank decided to reenter Denmark Academy and study Latin and Greek, then required for entrance to college. A year later a teacher of science was needed at the Academy, and arrangements were made which permitted Leverett to teach scientific subjects while pursuing his study of the classics.

Leverett's teaching of sciences at the Academy continued from 1881 to 1883, and during this period he became much interested in geology. Within easy reach of the Academy are exposures of the Mississippian (Burlington) limestone and also of the Coal Measures. Charles Wachsmuth at Burlington possessed a fine collection of fossils from both these formations and Leverett was accustomed to take his students to study these collections as well as visit the quarries and mines. In his own fossil collection was a plant which he was unable to identify from the published descriptions, so he sent it to the paleobotanical authority of the time, Professor Leo Lesquereux. It proved to be a new species and by Lesquereux it was named *Sigillaria Leveretti.*

This, Leverett's initial honor in the field of geology, stimulated further his desire to enter college and he considered seriously the University of Michigan, where Alexander Winchell occupied the chair of geology and was becoming widely known from his itinerant lectures and ultrapopularized books. On the advice of Colonel Brackett, and because of the geological features displayed on a grand scale in the vicinity, Leverett decided in favor of Colorado College at Colorado Springs. To this choice is probably due the change of Leverett's major in-

terest from paleontology to glacial geology,[a] for the incumbent of the chair of geology at Colorado College was Professor George H. Stone, already well launched on his career as glacial geologist, later to be signalized by a ponderous monograph on the glacial gravels of Maine and their associated deposits (Monograph U. S. G. S., xxxiv, 1899, 499 pages, maps).

With Professor Stone frequent geological excursions were made into the neighboring mountains, and in addition to geology Leverett gave considerable time to laboratory work in blowpipe analysis and assaying. He soon realized that he needed more laboratory work in physics and chemistry and in other natural history sciences, so in the fall of 1884 he entered the Iowa Agricultural College at Ames. There in addition to chemistry, physics, botany and zoology, he took other necessary courses in the curriculum and was graduated in November, 1885, with the degree of Bachelor of Science. At Ames he came under the inspiring teaching of a great scientist, the botanist Charles E. Bessey.

As his graduating thesis at Ames, Leverett completed a study of the local artesian well district, during which study he came into correspondence with W J McGee, then an amateur Iowa geologist, and with Professor T. C. Chamberlin at Madison, Wisconsin, who was in charge of glacial geology on the United States Geological Survey. Both these men read and criticized his thesis. On McGee's advice Leverett applied to Chamberlin for a position on the Survey and was invited to come to Madison for a conference. The journey from Denmark of two hundred and fifty miles was made by Leverett on foot, giving close attention throughout to the features within this area where his life work was to begin.

The budding glacialist was engaged on a temporary basis for a single year, but this was extended annually until 1890, when he was given a permanent appointment as assistant geologist. In 1901 he was advanced to geologist and in 1928, a year only

[a] This shift away from paleontology to a different branch of geology speaks for the strong influence of his teacher, for it is well known that our great paleontologists were started on their careers by having rich fossiliferous horizons near their early homes. Examples are Walcott, Schuchert, Ulrich, Bassler, Foerste and Twenhofel.

before his automatic retirement for age, to senior geologist. His retirement from the Federal Survey in 1929 closed a distinguished active career of forty-three years.

To quote from the autobiographical sketch:

"My work has been a steady expansion of the area under investigation, which has spread from the starting points in Iowa and Illinois over the entire glaciated part of the United States between the western limits of the Laurentide ice sheet in Kansas and the Atlantic Coast in New Jersey, and from the Missouri and Ohio valleys northward to the Canadian Boundary. I hastily examined several areas of mountain glaciation in Colorado, California and Washington, and in the Yellowstone National Park in the summer of 1916. I carried on a comparative study of European glacial deposits in the year 1908, and was greatly stimulated by the helpful guidance of the leading glacialists, notably Penck, Keilhack, Wahnschaffe, Kilian and de Martonne, as well as by our eminent American geographer W. M. Davis, who was at the time conducting excursions in the Alps."

For the most part the travels necessary to cover in such detail the North American glaciated area were made on foot, and Leverett himself has estimated that these in the aggregate were more than four times the circuit of our globe. The tough fibre inherited from his long-lived farmer ancestors doubtless in part explains this. His endurance was well known to all who had climbed in his company. He was never seriously ill, and his only tour in a hospital was for eleven months in 1920 with a broken hip. He had slipped on a rug as he rushed to the window to see if a passing cab was the one he had ordered to take him to the railroad station.

His indoor labors were no less untiring as he prepared the great reports which were marked by such meticulous accuracy that his statements were never seriously challenged. Utilized by highway engineers, his reports came to have an authority seldom accorded to the work of scientists. Leverett's memory was so retentive that a colleague's query concerning any locality brought out at once almost the complete glacial history.

Leverett's name is not connected with the more fundamental of the conceptions of glacial geology, most of which had been

formulated before his entry into the field. His studies formed however the foundation on which others have built in their elaboration of these early conceptions. Dr. T. C. Chamberlin, his chief in the Geological Survey, was accustomed to cite Leverett so frequently in his lectures at the University of Chicago that the students came to refer to Leverett as "Chamberlin's eyes."

On December 22, 1887 Leverett was married to Frances E., daughter of James and Anna (Frey) Gibson, who died July 10, 1892. He was married, second, December 18, 1895 to Dorothy C., daughter of Russell and Dorothea (Schmidt) Park, who survives him. There have been no children by either marriage.

In 1909 Leverett was made staff lecturer in glacial geology at the University of Michigan and each spring semester he delivered an elementary course of lectures and an advanced course on the "Comparison of European and North American Glacial Formations." An important feature of the advanced course was a number of long excursions from Ann Arbor through the glaciated area. These were greatly prized by those privileged to participate in them. After Leverett's retirement in 1929 the University of Michigan at the commencement exercises of 1930 conferred upon him the honorary degree of Doctor of Science.

The official publications of Dr. Leverett were issued by the Government in massive quarto monographs, professional papers and reports; in octavo bulletins and water supply papers; and in folio atlases, all luxuriously illustrated (See list at end). These included three massive quarto masterpieces published as Survey monographs. They are: The Illinois Glacial Lobe (Monograph XXXVIII, 1899, 817 pages and 24 plates); Glacial Formations and Drainage Features of the Erie and Ohio Basins (Monograph XLI, 1902, 800 pages and 26 plates); and (With Frank B. Taylor) The Pleistocene of Indiana and Michigan and the History of the Great Lakes (Monograph LIII, 1915, 529 pages and 32 plates). These and his other official publications much exceed in volume those of any other member of the Survey staff from its beginning. His many unofficial publications here appear in his bibliography as a separate list.

Honors in full measure came to Dr. Leverett. In 1891, the year after its foundation, he was elected a fellow of the Geological Society of America. He was a fellow and in 1928 a Vice President of the American Association for the Advancement of Science. In 1910 he was President of the Michigan Academy of Sciences, Arts and Letters, and for his presidential address chose "Outlines of the History of the Great Lakes." He was also a member of the Academies of Science of Iowa, Wisconsin and Washington (city), of the Geological Society of Washington, American Geographical Society, American Forestry Association, and American Geophysical Union. He was a corresponding member of the National Geographic Society, and a member of the honorary fraternities of *Phi Kappa Phi* and *Sigma Xi*. He was honored by election to the American Philosophical Society (1924), and to the National Academy of Sciences (1939).

Three natural monuments have been given Dr. Leverett's name. In 1891 an outlet glacier at the head of the Sondre Strömfjord in Southwest Greenland was named Leverett Glacier by the First University of Michigan Greenland Expedition. (Repts. Greenland Exped. Univ. Mich. 1926-1931, Pt. 1, 1931, map on p. 9). In the same year the First Byrd Antarctic Expedition gave his name to one of the largest glaciers discovered by the Expedition (Gould, Cold, the Record of an Antarctic Sledge Journey, pp. 210-212, 232, 1931. Also Some Geographical Results of the Byrd Antarctic Expedition, *Geog. Rev.*, vol. 21, No. 2, 1931, large folding map opposite p. 194). A few months only before his death a great Pleistocene ice-dammed lake of the type to which he had devoted so many years of study was given his name (*Science*, vol. XCVIII, No. 2541, Sept. 10, 1943, pp. 227-230). A fortnight before his death an excellent bust of Dr. Leverett was completed by the sculptor, Carleton W. Angell.

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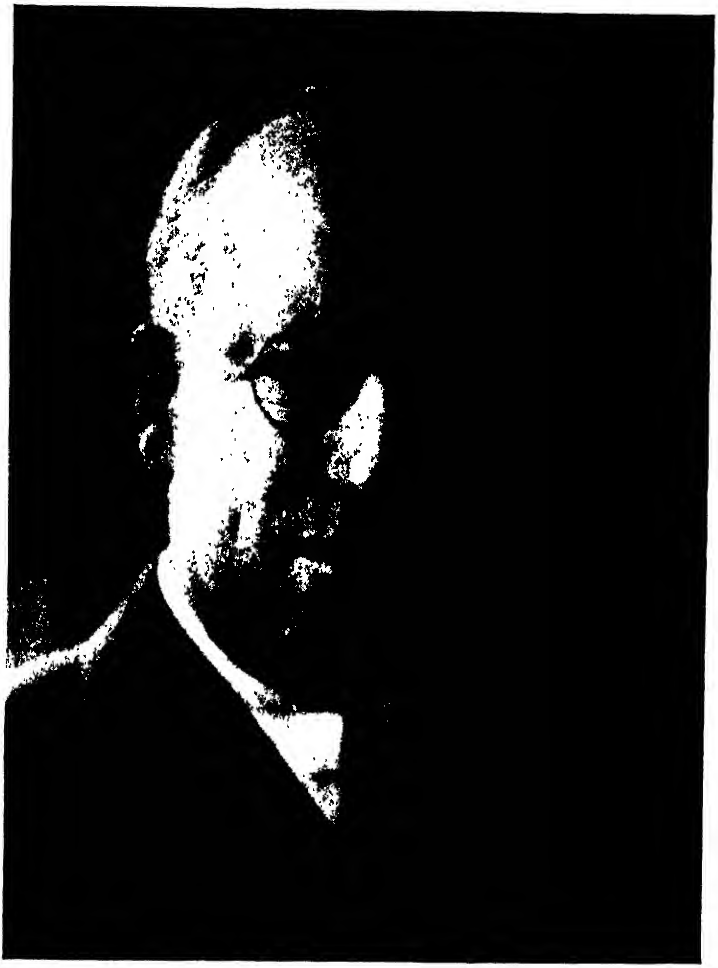

E. M. East

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OF

EDWARD MURRAY EAST

1879–1938

BY

DONALD F. JONES

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1944

EDWARD MURRAY EAST

1879–1938

BY DONALD F. JONES [1]

Since Edward Murray East was one of the world's distinguished students of heredity, it seems especially appropriate to begin a review of his life with a consideration of his hereditary background.

There is a tradition in the East family that Sir Isaac Newton was numbered among the collateral ancestors, but this is difficult to prove, since his grandfather, Isaac Newton East, left his home in boyhood and spoke but little of his people. There is, at least, no doubt that the distinctive name recurs in several generations, also the name of William Harvey, showing an interest and appreciation of men of science. On his mother's side the immigrant paternal ancestor was Matthew Woodruff, who in 1640 was a member of the colony which established Farmington, Connecticut. A great uncle, Ebenezer Bushnell, was a Congregational minister and an administrative officer in Western Reserve University. The biographer and poet, William Sloane Kennedy, was a cousin once removed on his mother's side. East's father, William Harvey East, was a man of considerable mechanical ability who studied mechanical engineering at the University of Illinois in 1875-1876 and later worked as a machinist, a manufacturer of machinery and chief engineer for a clay products firm. William Harvey East married Sarah Granger Woodruff; their only son, the subject of this sketch, was born at Duquoin, Illinois, on October 4, 1879.

With such an hereditary background, it is not surprising that East should have become interested in creative and scholarly pursuits or that the mental energy, the independence of thought

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ACKNOWLEDGMENT

[1] In the preparation of this biographical sketch the writer has been helped greatly by relatives, colleagues and students of the late E. M. East. Drs. P. C. Mangelsdorf, O. E. White and H. K. Hayes especially have made valuable suggestions and revisions of the manuscript. To Mrs. E. M. East the writer is grateful for corrections and additions.

and the strong desire for perfection, which characterized his later life, should have been foreshadowed in his ancestry and anticipated in his own precocious childhood. At an age when the majority of children were using the traditional childhood alphabet blocks for toys, young East was already framing words with the letters embossed upon them. Later he had the inevitable boyish collection of birds' eggs, but he also possessed, and studied diligently, a comprehensive treatise on birds purchased with money which he had earned by working in a grocery store during a summer vacation. Like many boys of his age, he eventually acquired a .22 rifle, but few ever became so expert as he as a marksman.

East finished high school at the age of fifteen and for two years worked in a machine shop. Here he became proficient in mechanical drawing and shop methods and gave evidence of inventive ability. After earning enough money to start in college he entered the Case School of Applied Science in Cleveland in 1897, partly because of a family interest there. He often mentioned to his own students, the mathematics professor at Case School who gave him a grade of zero on an examination paper because he had made a single error, explaining that a bridge or other mechanical structure with only one error in design might easily be worthless. This apparently made a deep impression upon him and may well have been a factor in the care which he always exercised in verifying all important statements of fact and in his insistence that his students maintain a high degree of accuracy. It should be noted, however, that his concept of accuracy was a flexible one. He avoided refinements in measurements which would be cancelled by the experimental error and he also quoted, at appropriate moments, a statement of a former chemistry instructor that "there is little to be gained by weighing a ton of hay on an analytical balance".

Finding that his interests were more in general science than in applied mechanics, he transferred, after one year at the Case School, to the University of Illinois. From this institution he received the degree of Bachelor of Science in 1900, Master of Science in 1904 and Doctor of Philosophy in 1907. His Master's thesis was based on chemical and bacteriological studies on

the self-purification of running streams. While working on this subject he devised an original method for obtaining samples of water.

Trained as a chemist, East became actively interested in genetics as a result of a combination of circumstances which deserve a brief review. Investigations in animal nutrition were being actively pursued at the turn of the century. Nutritive ratios were in the forefront and research in nutrition centered upon the proper balance of carbohydrates, fats and proteins. Indian corn, the great American feed crop, was usually deficient in both proteins and fats, but showed great variability in chemical composition. As early as 1892 Jenkins and Winton at the Connecticut Agricultural Experiment Station had compiled analyses of American feeding stuffs and showed that the corn kernel ranged from 8.2 to 17.0 per cent in protein content. Variations in fat content were also apparent. These wide variations, considered in connection with the notable success which had been attained in Europe in selecting beets for higher sugar content, suggested strongly that the chemical composition of corn might be considerably improved by breeding. Experiments to accomplish this, to alter the protein and fat content of corn, were begun at the Illinois Agricultural Experiment Station by C. G. Hopkins about 1900.

East's first scientific position was that of assistant chemist in Hopkins's laboratory. It was his job to make chemical analyses of the samples of corn involved in the selection experiment. This task he performed with accuracy and efficiency, but with little satisfaction to himself. He realized that the analyses, as such, served an important end; but that they were only tools in an experiment of considerable significance, and he was eager to understand the meaning of the results which were being obtained. Fortunately for him and for the infant science of genetics, his curiosity was kindled at a propitious time.

Long before the rediscovery of Mendel's laws of heredity Balzac had written that "heredity is a sort of maze in which science loses itself", but in 1865 an unknown Austrian monk published in an obscure journal the results of his classical experiments on heredity in peas. Overlooked by the majority of

scientists of the period, completely overshadowed by Darwin's epoch-making "Origin of Species", and as East himself later pointed out, presented to the scientific world before it was prepared to grasp its significance, Mendel's work lay dormant for thirty-five years. Its rediscovery came at a time when interest in heredity, as an evolutionary mechanism on the one hand, as the basis of plant and animal improvement on the other, was at a high pitch. An "International Conference on Hybridisation and on the Cross-breeding of Varieties" had been held in England in 1899. The American Breeders' Association was founded at a meeting held in St. Louis in 1903 in connection with the American Association for the Advancement of Science. Its second meeting was held at the University of Illinois in February, 1905. Among the list of members appears the name of E. M. East.

The Illinois experiments on altering the chemical composition of corn attracted widespread attention. And nowhere, perhaps, were they followed with greater interest than at New Haven, where much of the pioneer American research in nutrition had been conducted by the Connecticut Agricultural Experiment Station in close collaboration with Yale University. It was only natural that E. H. Jenkins, a chemist, when he became Director of the station and decided to expand the work in plant breeding should have thought in terms of improving chemical composition. It was only natural, too, that he should have asked Hopkins to recommend a young man to undertake the new work. East was recommended, accepted the appointment, and came to New Haven in the fall of 1905.

Although East spent only four years in residence at the Connecticut station, these years were, from the standpoint of research, the most productive in his life. He carried on intensive studies on three economic plants, the tobacco, potato, and maize.

His work with potatoes was largely devoted to a study of variation in a vegetatively propagated plant. Part of the results were incorporated in a thesis submitted to the University of Illinois in completion of the requirements for the Doctorate and later published as a bulletin of the Illinois station. Other papers

on inheritance in potatoes appeared in an annual report of the Connecticut station and in the American Naturalist.

His early work on tobacco, although largely of a practical plant breeding nature, laid the foundation for his later genetic research on species of Nicotiana in which he made numerous important contributions.

His most far-reaching experiments of this period were those on maize. It was during this period that he began the study of mendelian characters in maize, the results of which were published with H. K. Hayes in 1911 as a bulletin of the Connecticut station entitled "Inheritance in Maize", one of the classics in the early literature of genetics. It was in maize, too, that he discovered independently of Nilsson-Ehle, the phenomenon now known as multiple factors which, as East recognized almost immediately, provide an orthodox mendelian interpretation for quantitative or "blending" inheritance, then still regarded by many biologists as a separate category of inheritance.

From the standpoint of both theoretical interest and subsequent significance to plant improvement, perhaps East's most important work during his brief stay in New Haven was that upon the effects of inbreeding and cross-breeding. Even before he left Illinois, East had become interested in this subject, for it had become apparent in the Illinois selection experiments that increases in protein and oil content, resulting from selection, were being accompanied by decreases in yield. East suspected that this might be the result of inbreeding for although the plants were not being self-pollinated, intensive selection was constantly narrowing the network of descent. He urged Hopkins to undertake an experiment on the effects of inbreeding in corn. Unsuccessful in this, he, characteristically, initiated some experiments of his own. The records of the dates at which these early experiments on self-fertilization were started are conflicting. A statement in one of his papers in the American Naturalist would indicate that the first selfings were made in 1904. A report in one of the Connecticut Station Bulletins would suggest that they were made in 1905. In any case, the experiments were begun in Illinois and were continued in Connecticut. The first crosses between inbred strains were grown in 1908, and his

first paper on the subject was published in 1908, a second in 1909, and a third with H. K. Hayes in 1912. The experiments were continued by H. K. Hayes and later by D. F. Jones. East never lost his interest in the subject of inbreeding and cross-breeding. His first book "Inbreeding and Outbreeding" published in 1919 with D. F. Jones was on this subject. One of his last papers "Heterosis" published in 1936, was on the same general subject.

The experiments of G. H. Shull at the Carnegie Institution, Cold Spring Harbor, those of E. M. East at the Connecticut station, and other investigators were destined to lead eventually to the development of a radically new method of corn breeding which has had revolutionary effects upon American agriculture. In 1943 more than 50 million acres, approximately half of the corn acreage in the United States, was planted to hybrid corn produced by combining inbred strains.

East's part in the development of hybrid corn is an important one. His investigations with self-fertilized maize were begun on his own initiative to study the effects of inbreeding. He was familiar with the work of Darwin in England and the early corn hybridizers at the Illinois Experiment Station. He was interested primarily in the theoretical interpretation of the reduction following inbreeding and the increased growth resulting from crossing. In his first publications on this subject: "Inbreeding in Corn" (1908) and "The distinction between development and heredity in inbreeding" (1909) he outlined clearly the problem and proposed the stimulation hypothesis to account for hybrid vigor. According to this idea the injurious effects of inbreeding did not keep on accumulating but merely accompanied the isolation of individuals with different genetic constitution and ceased with the attainment of complete homozygosity. This conception he developed more fully with H. K. Hayes in "Heterozygosis in evolution and in plant breeding" (1912) and with D. F. Jones in "Inbreeding and Outbreeding" (1919). Later his ideas on this subject were developed further in a conception of an interaction between alleles and were published in 1936 under the general title of "Heterosis". His vigorous writings and clear presentation of experimental evidence from both corn

and tobacco did much to stimulate interest in the subject and its application to practical plant breeding.

The idea of crossing inbred strains of corn, first proposed by G. H. Shull, did not appear to him to be a practicable method for corn improvement. In a footnote to the American Naturalist paper (1909, p. 180) East says: "his method is more correct theoretically, but less practical than that of the writer." East proposed the crossing of selected strains or varieties that had not been reduced to uniformity. This was a slight modification of the method of crossing varieties previously suggested and tried by several investigators many years before, but which had not led to any important commercial utilization.

Correspondence between East and Shull shows clearly the part that both have had in developing the theoretical basis for hybrid corn. Shull's paper on "The composition of a field of maize" was read at the meeting of the American Breeders' Association held at Washington, D. C., January 28-30, 1908. East attended that meeting and wrote Shull as follows:

New Haven, Connecticut,
February 5, 1908.

Dr. George H. Shull,
Station for Experimental Evolution,
Cold Spring Harbor, Long Island, New York.

MY DEAR DR. SHULL:

Would it be possible for you to let me read a copy of your interesting paper on maize, if you have a duplicate of it? The published report of the American Breeders' Association will probably not be issued before next fall. I should like to study your results before spring planting, if possible.

Thanking you in advance for this favor, I am,

Very truly yours,

(Signed) E. M. EAST.

February 12, 1908.

DEAR DR. SHULL:

I am returning under separate cover, the copy of paper on corn breeding, which you so kindly let me have. I have had a copy made which I shall keep. Since studying your paper, I agree entirely with your conclusion, and wonder why I have

been so stupid as not to see the fact myself. . . . I expect to quote from your paper and add some data of my own in a forthcoming report from this station, also to obtain more data upon the subject this summer in connection with some corn crossing experiments.

Very sincerely yours,

(Signed) E. M. EAST.

To this letter Shull replied:

Santa Rosa, California,
March 3, 1908.

DEAR DR. EAST:

Your favor of Feb. 12, enclosing the copy of my paper on corn breeding was received before I left Cold Spring Harbor. I am glad to find that your extensive experiments in corn breeding might have led you to the same conclusion as that at which I have arrived, and that you are going to base your experimentation to some extent upon this view. I am convinced that there is a wide open field here which has not been touched heretofore. There is little doubt in my mind that if I had held on to my idea of the composition of a field of corn until I could have worked out some of the subsidiary problems, I could have raised a monument to myself which would be worthy to stand with the best biological work of recent times. But the matter seemed to me of too great importance in view of the value of our maize crop to selfishly keep it to myself longer than was necessary to assure myself of its correctness.

Very sincerely yours,

(Signed) GEO. H. SHULL.

In June, 1908, East visited Shull at the Station for Experimental Evolution at Cold Spring Harbor and they went over together the evidence Shull had obtained that self-fertilization merely separated out pure lines which were inferior because they lacked the stimulating effect of a heterozygous condition. As a result of his 1908 experiments Shull prepared a paper on "A pure-line method in corn breeding," which was read at the meeting of the American Breeders' Association at Columbia, Missouri, early in January, 1909 and published in volume 5 of the proceedings.

Under date of February 4, 1909, East wrote to Shull as follows:

Dr. George H. Shull
Station for Experimental Evolution
Cold Spring Harbor, Long Island, N. Y.

DEAR DR. SHULL:

I hasten to answer your letter which I received yesterday enclosing the article which you read at the January meeting of the American Breeders' Association. I did not know that you were continuing this work as you told me in the summer that you did not have land enough to carry on things as you wished and should be glad if the work was taken up in other places. You know that I have had work going on since 1902 studying crosses and self-fertilized maize, but your article of last year gave me the idea which I was not bright enough to see for myself, namely, that self-fertilization was bringing out the homozygous characters.

The receipt of your article rather surprises me, as early in January I had sent an article to the American Naturalist coming to somewhat the same conclusions as you have. I enclose a carbon copy of this article, but I should be glad to have it returned, if this is not asking too much. In this article I thought that my idea of the distinction between deterioration due to the recombination of hereditary characters, and that due to the depriving of the homozygote of the stimulation due to the cross was a new idea. I rather believe from reading your second paper that you have something of the same idea, but you did not express it in your first paper, and do not make the statement clear in your second paper, which rather surprised me, for if you have this idea it seems to me it is the most important part of the whole matter. From the experience that I have had in pedigree breeding, I feel that the method I have outlined will be much more practical than the one you have outlined in your paper, for this reason, that no matter how the line breeders of the Middle West are selecting, they are in reality inbreeding. I have followed a number of varieties, and pedigrees invariably trace back to a single ear, in from four to six years from the start. The very methods of the so-called corn judge, with the great stress that he gives to uniformity, tend to inbreeding. The method I have outlined is the method for the corn grower,—not the corn breeder.

I wish you could have a little experience trying to get the farmers to take up anything in the least complex, and I know you would agree with me that only the very simplest things can be done by the corn grower. I should be glad to know whether

your idea of the theory in this matter is the same as I have expressed in this article. . . .

Very truly yours,

(Signed) E. M. EAST.

Shull's reply to this letter was in part:

". . . I care very little for the question of priority. What we are most concerned in is the *triumph* of the *truth* and especially of *useful* truth, and it is very gratifying to me that you should find in your extensive and careful experimentation the evidence which has led you to the conclusions so well presented in this paper. . . . You must have misunderstood me in the summer, if you thought I was expecting to abandon my corn experiments. I am going on with them and each year that they are continued makes them more valuable. But just as I told you, I am so limited by considerations of space and my own strength that I must continue them on the relatively small scale I have been using in the past, and cannot branch out onto the questions having purely practical bearings. These seemed to call for larger experiments than I can conduct here, and I hoped for this reason to be able to interest the Agricultural stations in the matter."

And finally on February 9, East sent this note:

". . . I freely admit that your paper of 1908 [The Composition of a field of maize] gave me the first idea of inbreeding separating the biotypes and that on this hinged the whole matter. The later paper is its logical conclusion. . . [Dr. Jenkins] came into my office on the day I received your first paper and I was happy as a lark and told him Dr. Shull had just sent me a paper that gave us the "hunch" we had been wanting about our inbred corn plants. . . ."

About this time, or soon after, East received the offer to go to Harvard University, which he did in the autumn of 1909. There his interests centered on his Nicotiana investigations. After an early attempt to interest some of the western seed corn producers in the production of first generation hybrid seed he gave less attention to the applied phases of this problem, turning this over to Dr. H. K. Hayes who succeeded him at the Connecticut Experiment Station, working under his direction and studying at Harvard University. At this time investigations dealing with selection in self-fertilized lines were begun using both maize and tobacco. The book on inbreeding and outbreed-

ing, published many years later, was outlined as early as 1912.

East was appointed Assistant Professor of Plant Morphology at the Bussey Institution of Harvard University. This institution, originally established in 1871 as an undergraduate school of agriculture, was reorganized in 1908 for research and advanced instruction in subjects related to agriculture and horticulture, and in 1915 became the Graduate School of Applied Biology. Its faculty comprised a small but distinguished group of biologists including William Morton Wheeler, William E. Castle, I. W. Bailey and others. East's appointment to the Bussey faculty came largely as a result of a recommendation by Professor William Bateson of the University of Cambridge, England's pioneer geneticist, who had become acquainted with East and his work while giving the Silliman Lectures at Yale University. East was promoted to Professor in 1914, and his title was changed to Professor of Genetics in 1926. In the interval he was offered appointments in a similar field at Cornell University and Princeton University, as well as the presidency of one of the state agricultural colleges.

During the years 1908 to 1918 he collaborated in tobacco breeding investigations with the Bureau of Plant Industry of the United States Department of Agriculture, and continued for a number of years to act in an advisory capacity to the Connecticut Agricultural Experiment Station and followed the investigations there with keen interest. He had the greatest admiration and respect for Dr. E. H. Jenkins, director of the Connecticut Experiment Station, who was always ready with encouragement and advice during those first years when East was working to establish a name for himself in the scientific field.

At the Bussey Institution, East's interest in research continued unabated. He amplified the studies, initiated at New Haven, on inheritance of quantitative characters and published several papers which are still widely cited in genetic text-books, and which have served as models for much of the subsequent work in this field of genetics. His interpretation, together with that of Nilsson-Ehle, of the inheritance of quantitative characters on the basis of multiple, cumulative factors brought all heredity under the consistent principle outlined by Mendel.

He began the studies, to which he was to devote many years, on the genetics of self-sterility in plants and its evolutionary and physiological significance. These studies resulted finally in the concept of oppositional alleles. The idea was first proposed by A. J. Mangelsdorf who was at that time a graduate student and assistant. This was firmly established by East's extensive investigations and brought order in a chaotic and conflicting mass of observations upon many different plants and animals. His last paper, published posthumously, was devoted to a survey of the distribution of self-sterility in flowering plants. He made a series of studies on the genetics and other biological aspects of species hybrids in Nicotiana and Fragaria. The versatility of his interests included microscopic studies of cell morphology, immunological reactions in plants, and studies at the Harvard Botanical Gardens in Cuba in collaboration with Dr. W. H. Weston, on virus diseases.

But although his investigations during nearly 30 years at Harvard were extensive, versatile in scope, and productive, they appear, in perspective, to have been overshadowed by his influence as a teacher. As a class-room teacher he was not an unqualified success. His course in genetics at Harvard was never especially popular with undergraduate students, although he devoted much time and effort to it and capable students often got more from his lectures than from those of others at the time more popular. But with graduate students the story was quite different. His methods, if indeed he consciously utilized definite methods, were unconventional. Certainly there was no uniformity about them. With all of his students he tried to be helpful, sometimes in ways they did not recognize or appreciate. As for most students, the purchase of clothing was to the writer a problem of great financial magnitude. Arriving in Boston from New Haven one time with a pair of well worn and badly faded rubbers he asked if I had walked all the way. Quite appropriately he mentioned on another occasion that a haircut sometimes might be worth at least a thousand dollars to any man. For himself he set an example of productive work and attention to important details that was difficult to equal. With some of his students he was brusque, stern and apparently unduly critical, with

others he was extremely kind, fatherly and affable, but when necessary he could be brutally frank. Whether he made these distinctions consciously, is not known. The fact remains that his methods were effective. To the great majority of his students he imparted not only a firm grasp of the principle of genetics, but usually also something of his own critical attitude, his passion for accuracy, his recognition of the relativity of scientific truths and not infrequently an interest in literature, history and the arts. He was an educator in the true sense of the word. A list of his former students is a roster of distinguished and successful geneticists in all parts of the world.

Beginning with World War I, during which he served as a chairman of the Botanical Raw Products Committee of the National Research Council, and also as Acting Chief of the Statistical Division of the United States Food Administration, East's interests turned increasingly to the implications of biology to world problems and human affairs. His work in the Food Administration had shown him how narrow is the margin between the world's food supply and its ever increasing needs. His experience in agricultural research had convinced him that the usual estimates of increased production which could be expected from improved agricultural practices were far too optimistic. At about this time he also read for the first time Malthus' "Essays on Population," the treatise which had given Darwin the key to his theory of natural selection as a consequence of a perpetual "struggle for existence." East realized that the fulfilment of Malthus' dire predictions had been merely delayed by industrial developments and advances in agriculture; that the Malthusian Law was still valid and that the world faced poverty, misery, and widespread starvation unless the growth of populations were restricted. These conclusions were lucidly expounded in his "Mankind at the Crossroads" published in 1923, and later translated into German and Italian. Published at a time when the United States was beginning to suffer from a plague of crop surpluses and low agricultural prices, as a consequence of war-time expansion and wide-spread adoption of improved agricultural machinery, the book, though widely read, was severely criticized and even ridiculed in some quarters. It

has required another World War and the adoption of an international view-point on world population problems and food supplies to show that his conclusions are essentially sound. This book was followed by "Heredity and Human Affairs" (1927) an exposition of the principles of heredity and their bearing on social problems, and "Biology in Human Affairs" (1931, with other scientists) which was selected by the American Library Association as one of the 50 outstanding books of the year.

East's writing combined to an exceptional degree complete scientific accuracy with a lucid and effective prose. This was also true of his lectures which were numerous. He was lecturer at the University of Chicago (1911) at the Graduate School of Agriculture, University of Missouri (1914), at Ohio State University (1927) and at the University of Michigan (1931). He was De Lamar Lecturer at Johns Hopkins University (1920), Larwill lecturer at Kenyon College (1927), Harvey lecturer at the New York Academy of Medicine (1931) and held the Harvard lectureship at Yale University (1924-25). The honorary degree of LL.D. was conferred on him by Kenyon College in 1926. He conducted a round table on population problems in 1925 at the Institute of Politics at Williamstown, Massachusetts, in which he invited Henry A. Wallace to take part. This was the beginning of Mr. Wallace's active participation in national affairs.

East was a member of and took an active part in many scientific societies. Apparently his earliest affiliation was with the American Breeders' Association, now the American Genetic Association. He held membership in the American Association for the Advancement of Science, the Botanical Society of America, and the Genetics Society of America (Chairman of Genetics Section 1923, President 1937). He was elected a member in the American Society of Naturalists (President 1919), Fellow in the American Academy of Arts and Sciences, corresponding member of the Philadelphia Academy of Natural Sciences and member of the American Philosophical Society and the National Academy of Sciences. He was one of the founders of the journal, Genetics, and served on its editorial board for many years, taking an active interest in the publication, passing

on many of the manuscripts submitted, and assisting succcessive managing editors in numerous ways. He took an active part in the Sixth International Congress of Genetics held at Ithaca, N. Y., 1932, serving as a member of the committees on organization and publication, and as chairman of the program committee. He attended the fifth congress which was held in Berlin in 1927, and was looking forward with eagerness to attending the seventh which was held in Scotland in 1939. He was a member of the committee of fifteen which organized the International Union for the scientific investigation of population problems in Paris in 1928 and was elected chairman of its commission on food supplies in relation to population.

All his life he was an inveterate reader. All evening, every evening, whenever possible, he read as his father had before him. For years his reading interests were in scientific works and literature, then art, particularly etchings and prints. As he grew older and was too tired at night to do heavy reading he read detective stories, one book an evening. He spent much time in second-hand book stores and built up an excellent library. He had a collection of prints and etchings that gave him a great deal of pleasure. Although an extensive reader he always enjoyed being with others and was an entertaining and instructive conversationalist.

In all of his activities, research, teaching, writing, lecturing and participation in the affairs of scientific organizations, East was a perfectionist. This trait he exhibited even in his hobbies, indeed it was in his recreation that it was perhaps most clearly revealed, for here he was free to abandon activities in which he could not excel. He gave up golf when he found that he could not bring his score below 80, a figure which would have delighted many golfers. Billiards, however, furnished an adequate recreational outlet and he became an accomplished billiardist, playing a game equal in some respects to that of professionals. Perfection, in his eyes, was something to be desired and to be striven for yet it was neither a fetish nor a blind passion. He made a clear distinction between the essential and the nonessential. His experiments were carefully planned and the data were critically analyzed, but field and greenhouse notes

were frequently taken on the margins of letters which he happened to have in his pocket. He was always concerned with the problem of obtaining fair and adequate samples, but his measurements were never more accurate than required because of the limitations of the experimental error. Having a remarkable memory he sometimes leaned upon it too strongly for some of his facts and figures. He abhorred deceit, sham and dishonesty, and yet he recognized more clearly than most scientists that scientific truth is relative and not absolute; that the "truths" of today are no more than stepping stones toward the greater, but still relative truths of tomorrow.

Perfectionists are by their very nature frequently lacking in close friends. This was not true of East. He had many warm friends during his lifetime. In college he was a member of the Delta Kappa Epsilon fraternity. In Boston he enjoyed his association with the Harvard Club. True, he was regarded by many whose acquaintance with him was no more than casual, as cold and austere, but to those who knew him well, he was a man of strong friendships and intense loyalties. Scientific objectivity did not penetrate deeply into this sphere of his life, for it was difficult for him to recognize faults in his friends. His own loyalties were strong and he engendered strong loyalties. One of the deepest satisfactions of his last years, when he was frequently afflicted with illness, stemmed from the expressions of respect and friendship which he received from many of his former students.

Dr. East was married, September 2, 1903, to Mary Lawrence Boggs, daughter of Lieutenant William Brenton Boggs, U. S. N., and granddaughter of Pay Director W. B. Boggs, U. S. N. There are two daughters, Elizabeth Woodruff (Mrs. Ralph L. Drapeau) and Margaret Lawrence (Mrs. Donald L. Gillum).

Shortly after his 59th birthday, Edward Murray East died at Boston, Massachusetts, November 9, 1938. Genetics lost one of its best known pioneers and leaders. A man of rich and versatile talents, a careful worker, a keen thinker, a scholarly writer and able lecturer, he will be remembered by his students and colleagues also as a wise counselor and friend.

BIBLIOGRAPHY OF EDWARD MURRAY EAST

KEY TO ABBREVIATIONS

Amer. Breed. Assn. Rpt.=American Breeders Association Report
Amer. Jour. Bot.=American Journal of Botany
Amer. Nat.=American Naturalist
Arch. Néer. Sci. Exact. et Nat.=Archives Néerlandaises des Sciences Exactes et Naturelles
Biol. Centr.=Biologisches Zentralblatt
Birth Control Rev.=Birth Control Review
Bot. Gaz.=Botanical Gazette
Breed. Gaz.=Breeders Gazette
Brooklyn Bot. Gard. Mem.=Brooklyn Botanical Garden Memoirs
Bussey Contr.=Bussey Contributions
Conn. Agr. Exp. Sta. Bull.=Connecticut Agricultural Experiment Station Bulletin
Conn. Bd. Agr. Rpt.=Connecticut Board of Agriculture, Report
Cont. Lab. Gen. Bus. Inst.=Contributions, Laboratory of Genetics, Bussey Institution
Ill. Agriculturist=Illinois Agriculturist
Ill. Agr. Exp. Sta. Bull.=Illinois Agricultural Experiment Station Bulletin
Ill. Agr. Exp. Sta. Cir.=Illinois Agricultural Experiment Station Circular
Jour. Agr. Res.=Journal of Agricultural Research
Jour. Amer. Chem. Soc.=Journal, American Chemical Society
Jour. Gen. Physiol.=Journal of General Physiology
Jour. Hered.=Journal of Heredity
Mem. Hort. Soc., N. Y.=Memoirs, Horticultural Society of New York
Neb. Agr. Exp. Sta. Res. Bull.=Nebraska Agricultural Experiment Station Research Bulletin
Pop. Sci. Mon.=Popular Science Monthly
Proc. Amer. Acad. Arts & Sci.=Proceedings, American Academy of Arts and Sciences
Proc. Amer. Phil. Soc.=Proceedings, American Philosophical Society
Proc. Nat. Acad. Sci.=Proceedings, National Academy of Sciences
Rpt. Conn. Agr. Exp. Sta.=Report, Connecticut Agricultural Experiment Station
Rpt. Conn. State Bd. Agr.=Report, Connecticut State Board of Agriculture
Rpt. Soc. Prom. Hort. Sci.=Report, Society for the Promotion of Horticultural Science
Sat. Rev. Lit.=Saturday Review of Literature
Sci. Mon.=Scientific Monthly
Scribner's Mag.=Scribner's Magazine

U. S. Dept. Agri., Bur. Plant Ind. Bull.=United States Department of Agriculture, Bureau of Plant Industry, Bulletin
Ztschr. ind. Abst. u. Vererb.=Zeitschrift für induktive Abstammungs-und Vererbungslehre

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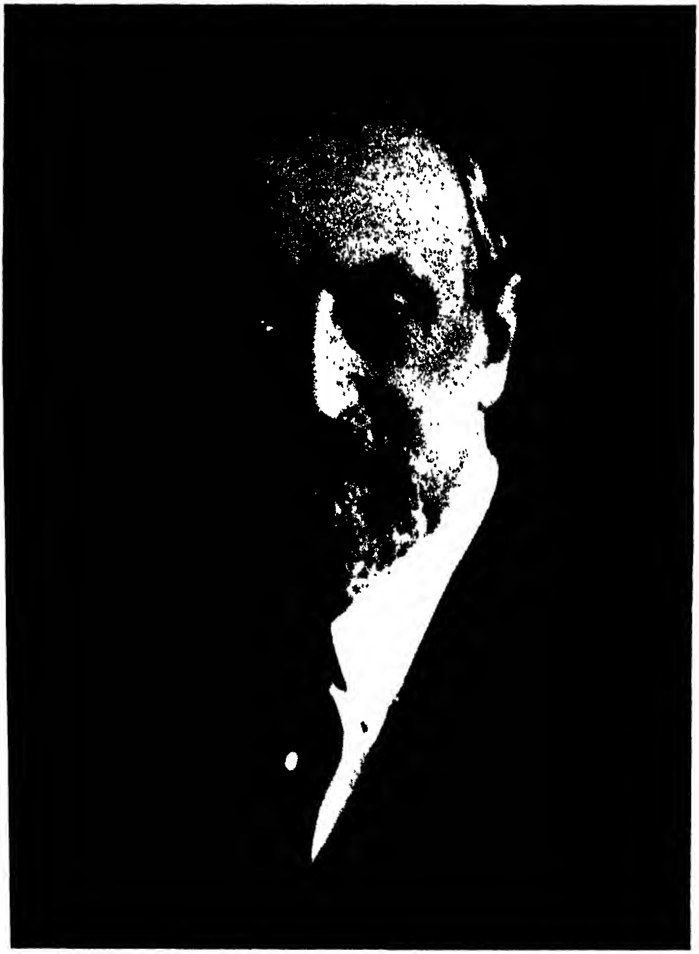

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BIOGRAPHICAL MEMOIR

OF

RALPH MODJESKI

1861–1940

BY

W. F. DURAND

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1944

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Ralph Modjeski was born in Cracow, Poland, January 27, 1861, son of Gustav Sinnmayer Modrzejewski and the renowned actress Mme. Helena Opid Modrzejewska. For purposes of American citizenship, the Polish form of the name was later changed to Modjeski (feminine form Modjeska).

There is little information available for the period of his early boyhood. From his own lips we have an account of an adventure with a screwdriver at the age of four years. (See later in connection with the "Washington Award.") Likewise, in his own personal statements and at several points in his mother's *Memories and Impressions*[1] there are references to his living with his grandmother in Cracow for attendance in that city at schools presumably corresponding to our grammar and high school grades.

During these years, 1861-76, his mother was for most of the time occupied with her theatrical engagements. Making her debut in 1861 in Bochnia, some fifty miles east of Cracow, in a benefit performance in aid of sufferers from a mine accident, she was soon the leading lady of a stock traveling dramatic company under the management of her husband. This led later to a life contract with the Warsaw Imperial Theatre, supplemented by incidental theatrical tours in other parts of Poland. During these years life in Poland, torn as it was politically, economically, and socially between Russia, Germany, and Austria, presented many difficulties and much unrest.

In view of these conditions and stimulated by glowing accounts of life in the new world to the west, especially in California, thoughts of the family began to turn to the question of a trip to the United States, at first considered only as a vacation from the exacting roles of the mother at the Imperial

[1] Macmillan & Co., New York, 1910.

Warsaw Theatre. Thus in her *Memories and Impressions,* referring to the Christmas season of 1875, she says:

"Then one morning during the Christmas holidays my son Rudolphe[a], whom I had sent to Cracow with my mother in order to place him in a Polish school, came to Warsaw to spend his short vacation with us. He was even then determined to become a civil engineer. The first thing he spoke of was the coming Exposition in America (Centennial 1876), and the lad, looking at maps, declared that some day he would build the Panama Canal."

This is of interest as showing that even at the age of fourteen years he had set the goal for his life work, although from other evidence it is known that music and a career as a professional musician formed a very strong rival attraction.

Enthusiasm and plans for the trip to the New World grew apace and soon took a definite form. Speaking of her son's keen desire to visit the United States, his mother, in her *Memories and Impressions,* says:

"Rudolphe adored traveling, as all boys do, but little he knew, when he expressed his wish and we half consented to it, what an enormous stride we were undertaking and what effect this little intimate talk was to produce on our lives, on his career and mine. He is now one of the successful civil engineers and bridge builders in America (written about 1908). Even then, in his boyhood, I was proud of him, and I had so much confidence in him that everything he desired seemed reasonable."

At about the same time, writing to her brother, referring to Rudolphe, she says:[8]

" * * * he takes at present piano lessons from Mr. Hofmann, and in seven lessons he learned four of Kohler's études by heart and almost the entire sixth sonata of Mozart. Besides this, he studies shorthand writing, languages, takes gymnastic exercises and horseback riding. With all these extra instructions he is always the first in his class and wonderfully strong in mathematics."

Then finally, with plans matured, a party comprising Mme. Modjeska, her husband and son, with five other young Poles,

[a] See later regarding change of name.
[8] Memories and Impressions, p. 246.

sailed in July of 1876 for New York, and after a brief stay for a visit to the Exposition in Philadelphia, pushed on via the Isthmus and by steamer from Panama to San Francisco, and thence to Anaheim in the southern part of California. There a ranch was purchased and plans for orange culture were made. Orange culture in practice, however, proved somewhat different from the anticipation, and the situation shortly resolved itself by the mother and son taking up residence in San Francisco, with the husband (stepfather of Rudolphe) alternating between Anaheim and San Francisco as conditions permitted or required.

It was during this period that the changes in the form of the names, earlier referred to, were brought about. In the case of the mother the change resulted from the objections of the celebrated actor John McCullough, at that time lessee of the California Theatre, San Francisco, to the full Polish form. At that time Madame Modjeska was about to make her American debut in that theatre, and the question of her name in the billing naturally arose. Mr. McCullough objected that the full Polish form would be unpronounceable by an English language tongue. Finally, by the omission of several letters, the Polish form was reduced to Modjeska as an acceptable substitute. It is also of interest to note that her son was first named Rudolphe and is frequently referred to under this name in her *Memories and Impressions*. Thus, relative to the period of their life in San Francisco just previous to the change in her own name, she says, referring to a short absence of her husband from home:

"He left me my son Rudolphe, who became at once my fellow student (English language). He then changed, with our approval, his name to that of Ralph, because, he said, Americans do not like long foreign names."

Thus, finally, Rudolphe Modrzejewski became Ralph Modjeski.

For about two years of this period of life in San Francisco, young Modjeski attended night school and then returned to Paris to complete his preparation for entrance to the École des

Ponts et Chaussées. This marked the turning point in his life. Essentially of an artistic temperament, he had been strongly attracted for a career, to music as well as to engineering and had debated with himself as to which line he should follow for his life work. In fact, when the family came to the United States there was still some thought that he might continue to follow this artistic urge through the medium of the piano, especially as an exponent of Chopin. At one point in her *Memories and Impressions,* his mother speaks of his playing Chopin's nocturnes at home while she, herself, was busy studying her English parts in anticipation of an engagement at the California Theatre in San Francisco. For a career in music he had been competently trained in Poland under Casimir Hofmann, son of the renowned Josef Hofmann, and had also at one time been a fellow student with his later illustrious compatriot Ignace Paderewski. Engineering, however, finally won the day, possibly at a loss to the world of a rival of his great Polish fellow countryman.

Thus finally, with the decision for a career in favor of engineering, he entered the École des Ponts et Chaussées in 1881 and graduated in 1885, leading his class, with the degree of Civil Engineer. Shortly after, he returned to the United States, probably with a better educational equipment for a career in engineering than could have been obtained in this country at that time. His first connection was with George S. Morison, the leading bridge builder of his day, and this first contact, extending till 1892, determined the direction taken by his later professional life. His first work with Mr. Morison was in connection with the construction of the Union Pacific Railroad bridge over the Missouri River at Omaha. Following this, 1887 to 1889, he took a turn at mill and shop inspection, followed by design work in the drafting room from 1889 to 1891, where, becoming chief draftsman, he supervised the design of the bridge across the Mississippi River at Memphis, Tennessee, and from 1891 to 1892 served as inspector of work in the shops and as assistant engineer of construction for the superstructure of this bridge.

Ambitious, and with his creative spirit seeking opportunity for more independent expression, Modjeski, as senior member of the firm of Modjeski and Nickerson, next opened a consulting and designing office in Chicago in 1893. The partnership, occupied with small projects, only lasted for a year and was then dissolved. In 1894 Modjeski received his first major project, the design and construction of a seven-span railway and highway bridge over the Mississippi River at Rock Island, Illinois. This bridge was built jointly by the Rock Island Railroad and the United States Government. A little later he developed a set of standard designs for steel bridges for the Northern Pacific Railroad, which remained effective for many years. From the date of this project on for forty-seven years, until his death in 1940, he held to the same specialized line of bridge design and construction, with a prodigious output of work, an output which has spread his name and fame, in this domain of engineering, broadcast over the country from the Atlantic to the Pacific.

The aggregate of this work is very great. The principal items, as a matter of record, are given in collected form as an appendix to this biographical sketch. Some of the more outstanding of these, however, deserve special note.

One of the most important of Modjeski's professional experiences was his collaboration with the late Alfred Noble, a past president of the American Society of Civil Engineers and an acknowledged leader in the United States in the field of bridge engineering. Long a friend of Mr. Noble, they joined forces in 1902 in a form of partnership. While working under this partnership Mr. Modjeski was appointed by the Southern Illinois and Missouri Bridge Company as chief engineer for the double-track railway bridge over the Mississippi River at Thebes, Illinois, and this was but the beginning of a long series of like important appointments.

In 1905, he served as chief engineer of reconstruction of the single-track railway bridge over the Missouri River at Bismarck, North Dakota, for the Northern Pacific Railway Company, and also in like capacity for new double-track rail-

way bridges in Portland, Oregon, over the Columbia and Willamette Rivers, these latter being also known under the name of the Vancouver-Portland Bridges. Then in 1906, he served in the same capacity for a new single-track electric railway bridge over the Illinois River at Peoria, Illinois, for the Central Illinois Construction Company. His next important work was the construction of a double-track railway and highway bridge over the Mississippi River at St. Louis, Missouri, known as the McKinley Bridge.

In 1907, the serious failure of the Quebec Bridge, over the St. Lawrence River about nine miles west of Quebec while still in construction, attracted world-wide attention. In 1908, the Dominion authorities appointed a three-man commission to advise regarding the redesign and reconstruction of this great project. Mr. Modjeski was named a member of this commission, representing American engineers, and served in this capacity until the final completion of the bridge in 1918. This bridge, at the time of its design and construction, was and still remains the longest cantilever bridge ever built.

During the span of years 1905-1915, Mr. Modjeski was the chief engineer for a series of bridges for the Oregon Trunk Railway Company between Celilo and Bend, Oregon. These included a single-track railway bridge over the Columbia River at Celilo and the notable 340-foot, two hinged arch spanning the Crooked River at a height of 350 feet above the stream. In 1910, he was also engaged by the City of Portland, Oregon, as chief engineer for the Broadway Bridge over the Willamette River. This structure was a double-track electric railway bridge, including a bascule span with roadways and sidewalks.

Sometime previous to 1912, plans for the bridge over the Maumee River at Toledo, Ohio, known as the Cherry Street Highway Bridge, had been prepared but not executed. Finally, in that year, Mr. Modjeski was engaged to redesign and construct this bridge. This was the first of a later notable series of concrete arch bridges designed by him.

In 1914, he was the designing and supervising engineer for

the construction of the Harahan Bridge, a double-track railway structure over the Mississippi River at Memphis, Tennessee, while at the same time he carried on the construction of a double-deck, single-track railway and highway bridge over the Mississippi River at Keokuk, Iowa.

His next work of importance was as consulting engineer in the preparation of the design for a double-track railway bridge over the Ohio River at Metropolis, Illinois. In this project he worked with the late C. H. Cartlidge and after the death of the latter was made chief engineer of the project. During this same period, two other projects of considerable magnitude were carried on. These were a double-track railway bridge over the Thames River at New London, Connecticut, and the other the reinforcement and the general reconstruction of the Poughkeepsie (N. Y.) railway bridge over the Hudson River.

In 1922, he served as the engineer of design and later as the consulting engineer of construction for the United States Government on the Tanana River Bridge in Alaska—a single-track railway bridge.

During the four years 1920-24, he also carried on the rebuilding of two bridges under traffic. One of these was the double-track electric railway and highway bridge with sidewalks, over the Ohio River at Cincinnati, and the other, the double-track electric and highway bridge over the Missouri River at Omaha, Nebraska. Following these projects, he was engaged as consulting engineer for the reinforcement of the cantilever span of the Columbia River bridge at Wenatchee, Washington.

During the period from 1923 to his death, Mr. Modjeski associated himself with a number of leading engineers, specialists in bridge design and construction. Thus in 1923, he formed a partnership with Frank M. Masters, to which was later added Clement E. Chase, and upon the death of the latter in 1933, his place was taken by Montgomery B. Case.

In connection with these partnerships, it is to be noted that following his connections with Mr. Morison, as noted earlier,

his more intimate business associations were made with members of his staff, younger men who had been trained up in the professional and technical atmosphere of his own office. Thus with Mr. Masters, Mr. Chase and Mr. Case, they were all former employees of Mr. Modjeski, and as time went on and opportunity served, they were taken into the partnership relation. This illustrates the human side of Mr. Modjeski's character and his interest in the advancement of the young men in his professional family. In addition to these more intimate business associations, Mr. Modjeski from time to time entered into temporary business relations with other eminent engineers for the study of special problems and the development of special designs. Thus at about this time he was associated with Mr. Daniel E. Moran, an eminent specialist in substructure and foundation engineering. This period (1923-1940) was one of prodigious output by Mr. Modjeski and his associates. Only the more important need be noted here.

As early as 1920, Mr. Modjeski together with George S. Webster and Laurence A. Ball had been selected by the Delaware River Joint Commission to form a Board of Engineers for the preparation of plans and estimates for the Delaware River Bridge at Philadelphia. The report of the Board was submitted to the Commission the following year and Mr. Modjeski was retained as chief engineer of the Commission, serving in this capacity during the period of construction and until the opening of the bridge to traffic on July 1, 1926. This bridge was Mr. Modjeski's largest and presumably most important single project, carried through primarily on his own responsibility as to engineering features and with the collaboration of the eminent architect Dr. Paul Cret, on architectural design and details. A notable feature in connection with this project is the fact that the date of actual opening to traffic was three days ahead of the date set by Mr. Modjeski in the preliminary report on the project. Also, at the time of its completion in 1926, this bridge had the longest suspension span ever built—1750 feet with a total length of bridge of 9570 feet.

During the period 1927-1929, four bridges of some note were built: a highway bridge over the Delaware River between Tacony, Pennsylvania, and Palmyra, New Jersey; the Ambassador Bridge crossing the Detroit River between Detroit, Michigan, and Sandwich, Ontario; a single-track railway bridge for the Texas and Pacific Railway Company over the Atchafalaya River at Melville, Louisiana; and a cantilever highway bridge over the Ohio River between Louisville, Kentucky, and Jeffersonville, Indiana. During the same general period Mr. Modjeski and his associates, together with Mr. Moran, designed and erected the Mid-Hudson Bridge at Poughkeepsie, New York, for the State of New York. This structure has been specially noted for the harmony of its Gothic design.

Then followed a wide variety of projects of varying magnitude and importance, spread wide over the country from Philadelphia, Pennsylvania, to Portland, Oregon, and from the Ohio River bordering Indiana to the Mississippi River at New Orleans. The latter structure (The Huey P. Long Bridge) deserves more than a mere mention of the name. The project had been under consideration and study over a long period of years. The foundation conditions under the Mississippi River at New Orleans had been considered as almost or quite beyond the reach of successful engineering treatment. Finally the problem was brought to Mr. Modjeski, studies were made and designs were prepared, but there was long delay in financing the project and the advancing years and failing health of Mr. Modjeski prevented him from taking as active a part in the work as was his normal habit. However, his engineering concept of the type of structure suitable for this most difficult river crossing was correct, was carried to a successful conclusion, and still stands as an example of a brilliant piece of engineering design and construction carried through under especially difficult conditions.

Mr. Modjeski's professional life was chiefly notable for the design and construction of large bridges. At the same time he was often called in as a consultant on projects with which his name may have had no official connection. Thus, in 1916 he was

appointed by the Public Service Corporation of New Jersey a member of a commission of three to report on the feasibility of a vehicular tunnel under the Hudson River, including preliminary plans and estimates; and again in 1925 he was engaged by the Western Electric Company to examine and check plans and specifications for their various industrial buildings. In 1909 in New York City he was called on to review and report on the design and construction of the Manhattan Suspension Bridge between Manhattan and Brooklyn, and also as supervising engineer for a part of the construction. Also, he was called on for a report on the contract plans and specifications for the major part of the Tri-borough Bridge over the East River, and report was made during the years 1930-1934. Still later, in 1935, he made a report to the Union of Soviet Socialist Republics on plans for the projected Palace of the Soviets in Moscow.

The last and the largest bridge project with which Mr. Modjeski was associated was the San Francisco–Oakland Bay Bridge. He was appointed in 1931, Chairman of a Board of Consulting Engineers for this undertaking, the longest major highway and electric railway bridge in the world, extending with its approaches over a length of eight and one-quarter miles. It was in Mr. Modjeski's office and under his guidance and inspiration that the preliminary plans were developed, including the adopted plan for the central concrete tower anchorage between the two suspension spans for the west bay crossing. Because of failing health, he was forced to make his permanent home in California from 1936 in order that he might be near the work on this great project. Due to increasing weakness, however, he was forced to become comparatively inactive during the last years of his life which came to an end June 26, 1940.

Thus passed a great engineer, a pronounced positive personality with a well deserved reputation as one among the greatest of the world's leading bridge engineers.

Mr. Modjeski's writings for publication were limited to numerous papers and reports on various phases of bridge en-

gineering, a list of the more important of which is given in the bibliography at the end of this memoir.

Reference has been made earlier to the rivalry between music and engineering as a career for Mr. Modjeski, and while engineering won out in the end, music still held for him an important place in his life. In spite of his intense absorption in his professional work, he found time to keep up his piano practice nearly every evening, and often for several hours on Sundays. The combination of a brilliant engineer with music on a professional plane is surely unique in the United States.

In personal character Mr. Modjeski was inclined to be reserved rather than expansive and did not readily make close friendships. Nevertheless, he did take a generous and deep interest in his associates and in the members of the engineering profession broadly. The existence of the Engineers Club of Chicago is attributed to his initiative resulting from his interest in engineering activities, his fellow engineers and their welfare.

An intimate personal friend of long standing has been quoted as saying that to understand him it must be appreciated that he inherited the temperament of an artist—not the artistic bias which is sometimes urged as the excuse for irrational behavior, but the delicate intuitive perception which insures balanced good taste and harmony in its outward expression, whether in music, art, architecture or engineering structures. In his professional work Mr. Modjeski always insisted on simplicity of treatment, with emphasis on function and purpose.

In this connection, the author of the biographical sketch prepared for the occasion of the award to Mr. Modjeski of the John Fritz Medal says: "Mr. Modjeski's engineering designs are characterized by sincerity, which is the basis of true art. The gracefully sweeping lines of the Delaware Bridge, the Gothic treatment of the Poughkeepsie Suspension Bridge towers demonstrate the beauty which is inherent in steel construction, when freed from attempts at embellishment or concealment by means of masonry and concrete. His work will serve to lead others away from ill-considered attempts to adapt architectural tradition blindly to the treatment of steel struc-

tures without recognizing the fundamental artistic values arising from straightforward expression of the action of forces and the manner of their resistance."

Mr. Modjeski's professional work has received notable recognition throughout the engineering world by way of honorary degrees, medals and prizes. Three times he received the honorary degree of Doctor of Engineering—in 1911, from the University of Illinois at Urbana, Illinois; in 1927, from the Pennsylvania Military College at Chester, Pennsylvania; and in 1931, from the Polytechnic Institute of Lwow, Poland; also, in 1931, the Washington Award jointly by the Western Society of Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers. In 1914, he received the Howard N. Potts Gold Medal; in 1922, the Franklin Medal; in 1924, the John Scott Medal (Franklin Institute); and in 1930, the John Fritz Medal.

Then in 1930, he was the recipient of two honors, the Grand Prize by the Polish Government at the Exposition of Industry and Science at Posen, Poland, and selection as a representative of the United States at the World Engineering Congress in Japan.

In 1926, the Republic of France made him a Knight of the Legion of Honor—a recognition in which he modestly but properly took great satisfaction.

On the occasion of the Washington Award in 1931, Mr. Modjeski made a brief acknowledgment which may be quoted here in full as giving his own statement of some features of his early life and of the conditions which led to the choice of engineering for his life work.

"Mr. President, Mr. Chairman, Ladies and Gentlemen: It is not fitting on this great occasion to speak very much about myself. I will only add to the brief outline that the Chairman has given of my life by saying how I became an engineer and why.

"When I was four years old I got hold of a screwdriver. This gave me an idea. I immediately investigated what this screwdriver was for and practiced on a door lock of the draw-

ing room of the house we lived in and took it all apart. I could not put it together again, and my father said, 'You will be an engineer.'

"I persisted in that until, as the Chairman said, I failed in the examination for entrance to the École des Ponts et Chaussées, where there were 25 places and 100 candidates. Then for about six months I practiced music six and eight hours a day. After six months I began to think, and at the end of nine months had thought out my problem and joined the preparatory school, then, three months later, I passed the examination into the École des Ponts et Chaussées.

"This is a great honor. I do not know how to express my gratitude to all the gentlemen who have awarded it to me. I prize it very highly; I prize it higher than any award I have received heretofore; and, ladies and gentlemen, I thank you."

Dr. Modjeski was naturalized an American citizen on August 7, 1887. He married first Felicie Benda on October 25, 1885, and following her death, Virginia Mary Giblyn, July 7, 1931. His children by the first marriage were: Felix Bozenta, Marylka Stuart, and Charles Emmanuel John.

He became during his lifetime a member of many technical and scientific societies, organizations and clubs. The more important of these are given in the Appendix. Of these various societies and organizations, the American Society of Civil Engineers represented his chief professional interest. Of this society he became a junior member December 1, 1886, an associate member July 1, 1891, and a member March 3, 1897, serving a term (1904-1906) as director or member of the governing body. In his earlier years with the society he contributed from time to time to its Proceedings by way of technical papers and discussions; but, with advancing years and more complete absorption in his consulting and field work, these contributions became less frequent.

Poland has given much to the world and much to the United States. From Kosciuszko on, down through the years, she has added to the debt we owe to her of genius and of service. The name of Ralph Modjeski takes its place properly on this scroll of honor.

APPENDICES *

I. Professional Papers and Reports Published By Ralph Modjeski

REPORT on Reconstruction of Rock Island Bridge over Mississippi River
Western Society of Engineers....1897

PAPER, Erection of the Draw Span of the New Rock Island Bridge
Western Society of Engineers....1897

PAPER, Northern Pacific Railroad Standard Bridge Plans
Western Society of Engineers....1901

REPORT to the Mayor and City Council with Plans and Estimates for the Proposed Bridge across the Willamette River at Portland, Oregon....1908

PAPER, The Celilo Bridge over the Columbia River
Western Society of Engineers....1912

REPORT to the Joint Pacific Highway, Columbia Bridge Committee of Portland and Vancouver Commercial Clubs, for the Proposed Bridge across the Columbia River between Portland, Orégon, and Vancouver, Washington....1912

SUPPLEMENTAL REPORT to the foregoing....1913

PAPER, Design of Large Bridges with Special Reference to the Quebec Bridge
Franklin Institute of the State of Pennsylvania....1913

PAPER, The Harahan Bridge over the Mississippi River at Memphis, Tennessee
Franklin Institute of the State of Pennsylvania....1917

PAPER, The Metropolis Bridge over the Ohio River at Metropolis, Illinois
Western Society of Engineers....1918

The Delaware River Bridge
Journal of Western Society of Engineers....1923

Special Problems in Bridge Design and Construction
Aldred Lecture, Massachusetts Institute of Technology....1924

Unusual Problems in the Design and Construction of Large Bridges
Franklin Institute of the State of Pennsylvania
(Centenary Lecture)....1925

PAPER, High Level Fixed Bridges over Navigable Waters
The American Association of Port Authorities....1926

PAPER, Structural Steel and Reinforced Concrete in Engineering
American Institute of Steel Construction, Inc....1927

PAPER, Suspension Bridges with Special Reference to the Philadelphia-Camden Bridge, U.S.A....1929
(World Engineering Congress, Japan)

* The material for these appendices has been drawn from data which were furnished by Dr. Modjeski for the files of the National Academy of Sciences

II. *List of Memberships in Learned and Technical Societies*

American Association for the Advancement of Science...........Fellow
American Institute of Architects..............................Member
American Institute of Consulting Engineers..........Member and Past Member of Council
American Philosophical Society................................Member
American Railway Engineering Association.............Charter Member
American Society of Civil Engineers.........Member and Past Director
American Society of French Legion of Honor.................Member
American Society for Steel Treating.........................Member
American Society for Testing Materials......................Member
Art Institute of Chicago................................Life Member
Association of Engineers (Former Students of L'École des Ponts et Chaussées of France)............................Member
British Institution of Civil Engineers........................Member
Engineering Institute of Canada..............................Member
Engineers Club of Philadelphia....................Honorary Member
The Franklin Institute of the State of Pennsylvania...Honorary Member
Metropolitan Museum of Art, New York City.................Member
National Academy of Sciences................................Member
New York State Society of Professional Engineers and Land Surveyors ....Director
Polish Institute of Arts and Letters.........................Member
Princeton Engineering Association..................Brackett Member
Western Society of Engineers.....Past President and Honorary Member

Clubs

The Century Association of New York.......................Member
The Chicago Engineers' Club...........................Past President
Engineers' Club of New York.................................Member
Engineers' and Architects' Club, Louisville, Kentucky..Honorary Member
Union League Club of Chicago...............................Member

III. *Chronological Record of Work*

1885- —After graduation came to America in early summer
First engagement, summer 1885 with Geo. S. Morison, C. E., as Assistant Engineer, Union Pacific Bridge, Omaha, Nebraska; Remained with Geo. S. Morison, C. E., from 1885 to 1892 in various capacities, as follows:

1885–1887—Assistant Engineer, Union Pacific Bridge, Omaha, Nebraska
1887–1889—Inspector in shops for bridge work, Athens, Pennsylvania
1889–1891—Chief Draftsman in office (during this time in charge of design of Mississippi River Bridge, Memphis, Tennessee)
1891–1892—Chief Inspector at shops for Memphis Bridge superstructure
1892 —Assistant Engineer of Construction, Memphis Bridge

1893 —Early in year, opened office in Chicago as Civil Engineer in independent practice.

1894–1895—Engaged by Chicago Rock Island and Pacific Railway Company to design a double track railway and highway bridge over Mississippi River at Rock Island, Illinois.

1894–1896—Chief Engineer of Construction of the above bridge for the Ordnance Department of the United States Army.

1898–1900—Prepared standard designs for steel bridges, (Spans 10 ft. to 250 ft. in length) for the Northern Pacific Railway Co.

1903 —Design and construction of fireproof warehouse for arsenal for the United States Government at Rock Island, Illinois

1902–1905—Thebes Bridge over Mississippi River, Thebes, Illinois. For the Southern Illinois and Missouri Bridge Company, new double track railway bridge, Chief Engineer (Built under firm name of Noble and Modjeski).

1905 —Bismarck Bridge over the Missouri River, Bismarck, North Dakota, for the Northern Pacific Railway Company, reconstruction of single track railway bridge, Chief Engineer.

1906 —Peoria Bridge over Illinois River, Peoria, Illinois, for the Central Illinois Construction Company (Illinois Traction System) new single track electric railway bridge, Chief Engineer.

1905–1908—Columbia River Bridge, Willamette River Bridge } both in Portland, Oregon
Commonly called the Vancouver-Portland Bridges, between Vancouver, Washington and Portland, Oregon, for the Spokane, Portland and Seattle Railway Company, new double track railway bridges, Chief Engineer.

1907–1910—McKinley Bridge over Mississippi, St. Louis, Missouri, for the St. Louis Electric Bridge Company (Illinois Traction System) new double track railway and highway bridge, Chief Engineer.

1910–1911—Celilo Bridge over Columbia River, Celilo, Oregon, for the Oregon Trunk Railway Company, new single track railway bridge, Chief Engineer. Also, during this period all bridges for the Oregon Trunk Railway Company between Celilo and Bend, Oregon, including a 340 ft. arch over Crooked River.

1910–1912—Broadway Bridge over Willamette River, Portland, Oregon, for the city of Portland, Oregon, new double track electric railway bridge, including a bascule span, with roadways and sidewalks, Chief Engineer.

1912 —Cherry Street Bridge over Maumee River, Toledo, Ohio, for the city of Toledo, Ohio, new concrete arch structure for highway traffic (Plans previously prepared by other parties and redesigned by Chief Engineer), Chief Engineer.

1914–1916—Harahan Bridge over Mississippi River, Memphis, Tennessee, for the Arkansas and Memphis Railway Bridge and Terminal Company, new double track railway bridge with wagon roadways, Chief Engineer.

1914–1916—Keokuk Bridge over Mississippi River, Keokuk, Iowa, for the Keokuk and Hamilton Bridge Company, double deck single track railway and highway bridge. Reconstruction, Chief Engineer.

1917 —Metropolis Bridge over Ohio River, Metropolis, Illinois, for the Paducah and Illinois Railroad Company (Chicago, Burlington and Quincy Railroad Company), new double track railway bridge. Consulting Engineer in preparation of designs in conjunction with the late C. H. Cartlidge; after his death Chief Engineer of Construction.

1917 —Thames River Bridge over Thames River, New London, Connecticut, for the New York, New Haven & Hartford Railroad Company, new double track railway bridge, Chief Engineer.

1917 —Poughkeepsie Bridge over Hudson River, Poughkeepsie, New York, for the Central New England Railway Company (New York, New Haven and Hartford Railway Company), single track railway structure—extensively reinforced—Chief Engineer in charge of reinforcement.

1908–1918—Quebec Bridge over St. Lawrence River, Quebec, Canada, for the Dominion Government of Canada, new double track railway bridge. Member (since formation in 1908) of Board of Engineers appointed by the Dominion Government of Canada, as representing the engineers of the United States, for the reconstruction of Quebec Bridge (longest truss span in the world). Served until completion.

1920-1922—Cincinnati Bridge over Ohio River, Cincinnati, Ohio, for the (Cincinnati, New Orleans and Texas Pacific Railroad Company), the Cincinnati Southern Railway Company, double track railway bridge with sidewalks (Old bridge rebuilt under traffic without falsework) Chief Engineer.

1922 —Tanana River Bridge over Tanana River, Nenana, Alaska, for the United States Government, single track railway bridge, Engineer of Design and Consulting Engineer on construction.

1922–1924—Omaha Bridge over Missouri River, Omaha, Nebraska, for the Omaha and Council Bluffs Railway and Bridge Company, double track electric railway and highway bridge with sidewalks, rebuilt under traffic, Chief Engineer.

1923–1925—Clark's Ferry Bridge over the Susquehanna River near Harrisburg, Pennsylvania, for the Clark's Ferry Bridge Company, concrete arch highway bridge, Consulting Engineer (F. M. Masters, Chief Engineer).

1923–1928—Market Street Bridge, over Susquehanna River, Harrisburg, Pennsylvania, for the Harrisburg Bridge Company, stone-faced arch highway bridge (In partnership with F. M. Masters).

1925 —Columbia River Bridge over Columbia River, Wenatchee, Washington, for the Great Northern Railway Company, single track railway bridge—Reinforcing cantilever span, Consulting Engineer.

1921–1927—Delaware River Bridge over Delaware River between Philadelphia, Pennsylvania and Camden, New Jersey, for the commonwealth of New Jesey and the City of Philadelphia, new highway suspension bridge with rapid transit and footwalks, Chief Engineer and Chairman of the Board of Engineers.

1927–1929—Tacony-Palmyra Bridge over Delaware River, between Tacony (Philadelphia), Pennsylvania, and Palmyra, New Jersey, for Tacony-Palmyra Bridge Company, highway bridge, Chief Engineer (Partnership with Modjeski, Masters and Chase).

1927–1929—Ambassador Bridge over Detroit River between Detroit, Michigan and Sandwich, Ontario, Canada, for Detroit International Bridge Company, highway bridge, Consulting Engineer for Owners (In partnership with C. E. Chase).

1927–1929—Atchafalaya Bridge over Atchafalaya River, Melville, Louisiana, for Texas and Pacific Railway Company, single track railway bridge, Chief Engineer.

1928–1929—Louisville Bridge over Ohio River, between Louisville, Kentucky and Jeffersonville, Indiana, for the Louisville Bridge Commission, highway bridge, cantilever type (In partnership with F. M. Masters).

1923–1930—Mid-Hudson Bridge over Hudson River, Poughkeepsie, New York, for the State of New York, vehicular and foot bridge, suspension type (In partnership with D. E. Moran).

1927–1931—Henry Avenue Bridge over Reading Tracks, Philadelphia, Pennsylvania, for Department of Public Works, City of Philadelphia, Pennsylvania, highway bridge (In partnership with C. E. Chase).

1927–1932—Henry Avenue Bridge over Wissahickon Creek, Philadelphia, Pennsylvania for Department of Public Works, City of

Philadelphia, Pennsylvania, stone and concrete arch highway bridge (In partnership with C. E. Chase).

1928–1931—Evansville Bridge over Ohio River at Evansville, Indiana, for Indiana State Highway Commission, cantilever highway bridge (In partnership with F. M. Masters).

1928–1931—Maysville Bridge over Ohio River at Maysville, Kentucky, for Kentucky State Highway Commission, highway suspension bridge (In partnership with F. M. Masters).

1929 —St. Charles Bridge over Wabash River, for Wabash Railway Company, Cantilever Bridge, Consulting Engineer.

1928–1931—Kentucky State Highway Bridges at Smithland over Cumberland River, Paducah, over Tennessee River (In partnership with F. M. Masters).

1931 —San Francisco-Oakland Bay Bridge (Trans Bay) for the State of California, highway bridge, Chairman, Board of Consulting Engineers.

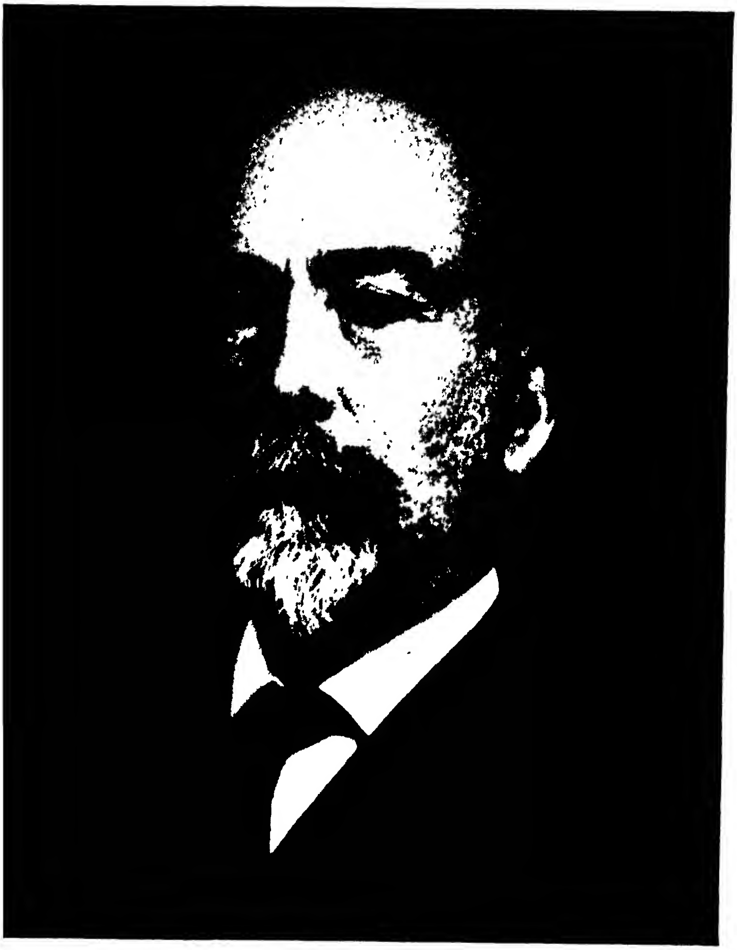
Also Consulting Engineer as Follows:

1909 —Engaged by the City of New York as Consulting Engineer to report on design and construction, also to supervise part of the construction of the Manhattan Bridge, New York, N. Y.

1916 —Appointed by Public Service Corporation of New Jersey as Member of the Commission of three, to report on feasibility of a vehicular tunnel under Hudson River, including preliminary plans and estimates.

1925 —Engaged by the Western Electric Company to check plans, etc., for industrial buildings of their various plants.

1930 —Engaged by the City of New York Department of Plants and Structures to report on proposed contract plans and specifications of the Tri-Borough Bridge over the East River, New York, N. Y.



W. M. Davis

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BIOGRAPHICAL MEMOIRS
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BIOGRAPHICAL MEMOIR

OF

WILLIAM MORRIS DAVIS
1850–1934

BY

REGINALD A. DALY

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1944

WILLIAM MORRIS DAVIS

1850–1934

BY REGINALD A. DALY

William Morris Davis won distinction as geologist, meteorologist, and geomorphologist, but primarily as teacher. He made personal, outdoor researches in every continent except Antarctica, as well as in island groups of the Atlantic and the Pacific; yet his international fame rests chiefly on his development of a system of thought concerning the reliefs, the scenery, of our planet. His system is the "American" system, but it is applicable to the landscapes of the whole world. His early training in geology led him to the principle by which he, more than anyone else, has revolutionized the teaching of, and research on, the endlessly varied forms of the lands and coastlines. To geographers and geologists alike he was an apostle bringing to them the gospel of method in research and method in the presentation of the results of research. For him the root of the matter is evolution, orderly development. Many geologists had used this principle, so essential to understanding the protean crust of the earth, but few geographers had used it in describing land forms. Davis emphasized a mode of thinking and for its expression he devised a system which has greatly appealed to teachers and investigators in many foreign countries as well as in the United States of America. While creating his descriptive method in terms of evolutionary changes, he found our English tongue sadly deficient. He had to create a new, necessarily technical language. Every man of science knows the difficulty of such an invention. Some of his verbal tools Davis was able to adopt from the literature of earth science, an immense literature which he thoroughly mastered; other vital terms were his own. The combination has been put to constructive use by geologists and geographers, foreign and domestic, to an extent encouraging to our pioneer. He lived to see notable improvement of geographical instruction in grammar school, high school, college, and university; improvement in the reporting of geographical and geological facts by staffs of the State

and Federal surveys; and improvement in the discussion of "terranes" by the more philosophically-minded historians and economists.

Knowing that even a long life could not vitalize all the dry bones of the old geography, Davis specialized on physical geography, leaving to others the problem of systematizing the infinitely varied responses of organisms to their environment. This other half of geography needs today a clarifying leader like Davis.

Davis was born in Philadelphia on February 12, 1850. At that time his father, Edward M. Davis, a business man, and his mother, Maria (Mott) Davis, were members of the Society of Friends and fully shared the best characteristics and activities of Quakers in full standing. Yet a hatred of injustice, which was to be an outstanding emotion of their son, led them into rebellion against one of the ironclad rules of the Society. Not content with helping to operate the "underground railway" for escaping slaves, Edward Mott enlisted in the Northern Army. For this action he was expelled from the Society of Friends and soon after his wife resigned from it. To both of them the question of States' rights was quite subordinate to the problem of human freedom. To break with the Society's tradition took courage of the kind shown in the remarkable life of Lucretia Mott, the mother of Maria Mott.

Theodore Tilton called Lucretia Mott, born in Nantucket, Massachusetts, "the greatest woman ever produced in this country." "She was the real founder and the soul of the woman's rights movement in America and England. She was the outstanding feminine worker in the struggle to rid our country of slavery. She advocated labor unions in a day when they were proscribed and generally considered illegal. She proscribed war, and worked diligently for liberal religion." Her crusading force "had its source in the love of freedom of her seafaring ancestry, and she feared opposition or the exploration of uncharted regions of the mind no more than they feared to venture into unknown seas" (quotations from Anita Moffett in the New York Times Book Review, August 1, 1937). That her

grandson was to be a crusader, a champion for mental and moral probity, was assured by inheritance from parents and grandparent.

As a boy Davis was retiring, little interested in sports, but engrossed in his studies. For several years before attending the local schools he was taught his lessons by his mother. She, like her own mother, knew well the power of words and laid much stress on their correct use; doubtless this early training had much to do with Davis's rigor in developing a scientific vocabulary for his favorite science and his insistence on precision of speech and writing by student or professional investigator.

The boy was a good student and showed his mental calibre by winning the Harvard degrees of Bachelor of Science at the age of nineteen and Master of Engineering a year later. He immediately accepted a call to the meteorological service of the National Observatory of Argentina at Cordoba. After three years of that routine work he returned to the United States. After a term as field assistant to Pumpelly in the Northern Pacific Survey, he was appointed (1877) to an assistantship in geology at Harvard, under N. S. Shaler, with whom he gained a permanent love for earth science. In those days promotion was slow and from 1879 to 1885 he was listed as instructor in geology at Harvard, where he began a five-year term as assistant professor of physical geography in 1885. In 1890 he attained the rank of full professor in the same subject. Nine years later he became Sturgis Hooper Professor of geology, a position held until 1912, when he resigned, to be a Harvard "emeritus" for the remaining twenty-two years of his life. He had two leaves of absence. In 1908 he was appointed visiting professor at Berlin University for a year, and, in 1911, visiting professor at Paris for a year, during which he lectured also at several provincial universities of France.

With his resignation Davis was freed from his responsibilities as active Sturgis Hooper Professor and found the eagerly-sought opportunity to make many postponed field studies both in North America and abroad, and also to make personal con-

tact with geographers and geologists and their respective workshops. Because he had a philosophy to expound, he could not refrain from accepting many invitations to lecture at western universities: California (Berkeley, 1927-1930); Arizona (1927-1931); Stanford (1927-1932); Oregon (1930); California Institute of Technology (1931-1932). With unfinished manuscripts on his desk at Pasadena he died in harness, on February 5, 1934, seven days before his eighty-fourth birthday.

The efficiency of Davis as a man of science was in no small part secured by domestic happiness. He was married three times and twice he suffered by the death of a partner. In 1879 he married Ellen B. Warner of Springfield, Massachusetts; in 1914, Mary M. Wyman of Cambridge, Massachusetts; and in 1928, Lucy L. Tennant of Milton, Massachusetts, who has survived him. All three women were truly sympathetic helpmeets, as the present writer knows from forty years of close association with this man, who needed much freedom from the cares of a household while working for and in the world outside.

The science of land forms, so intelligently enriched and organized by Davis is a planetary science; his message was addressed to geographers and geologists of every nation. That those colleagues recognized the vitality and soundness of his evolutionary ideas is indicated by the long list of honors showered on him by foreign as well as American societies. He was elected to honorary membership in the geographical societies of Amsterdam, Berlin, Budapest, Frankfurt, Geneva, Greifswald, Leipzig, Madrid, Neuchatel, New York, Petrograd, Rome, Stockholm, and Vienna, as well as the Royal Society of Natural History at Madrid, the American Meteorological Society, and the Scientific Society "Antonio Alzate" of Mexico; to corresponding-membership in the Berlin and Paris Academies of Science and the Accademia dei Lincei; to corresponding-membership in the geographical societies of Chicago, London, Munich, Paris, and Philadelphia, and the geological societies of Belgium, Liverpool, and London and the German Meteorological Society; to foreign-membership in the Academies of Sciences at Christiania, Copenhagen, and Stockholm. He was elected to

membership in the American Academy of Arts and Sciences, the American Philosophical Society, the National Academy of Sciences, the Imperial Society of Natural History in Moscow, and the New Zealand Institute.

The Geological Society of America made him its acting president in 1906 and full-time president in 1911. He founded the Harvard Travelers Club, of which he was president from 1902 to 1911, and the Association of American Geographers, of which he was thrice elected president (1904, 1905, 1909). For his leadership and scholarliness he was chosen to be an associate editor of "Science" and the "American Journal of Science."

In 1886 he was awarded the H. H. Warner Medal "for scientific discovery"; in 1895, another from the University of Paris. Later awards were: the Cullom Medal from the American Geographical Society (1908); a medal from the University of Berlin (1910); a medal from the Harvard Travelers Club (1911); a medal from the Geographical Society of Philadelphia (1912); the Culver Medal from the Geographical Society of Chicago (1913); the Kane Medal from the Philadelphia Geographical Society (1913); the Hayden Medal from the Philadelphia Academy of Sciences (1918); the Patron's Medal from the Royal Geographical Society, London (1919); the Vega Medal from the Swedish Geographical Society (1920); the Loçy Jagos Medal from the Hungarian Geographical Society (1930); and the Penrose Medal from the Geological Society of America (1931). He became Chevalier of the French Legion of Honor. As Exchange Professor to France he was the first American to give regular instruction at the Sorbonne.

Davis was given four honorary degrees: S.D. by the University of the Cape of Good Hope (1905) and by the University of Melbourne (1914); Ph.D. by the universities of Greifswald (1906) and Christiania (1911).

After his death the California Institute of Technology at Pasadena, where he had made many new friends, dedicated to Davis a memorial "Gate of Knowledge," one of the entries to the grounds of the Institute, whose students and faculty he had stimulated by his courses of lectures.

Work in Meteorology

Davis's interest in meteorology was doubtless aroused by his study of atmospheric conditions in Argentina, from 1870 to 1873. Soon after his appointment at Harvard he undertook his first pioneering task, the creation of a systematic course on the science of the atmosphere. This course became noted for its broad scope and for the clear, logical mode of presentation; in these respects it had no rival in America and probably none anywhere else. Fortunately he was able to put the content of the course in the permanent form of his "Elementary Meteorology," published in 1894, when the course was turned over to Robert DeCourcy Ward, a capable, Davis-trained student, who greatly expanded the university offerings in meteorology and added courses in climatology. This development, together with the founding of the Blue Hill Observatory as a Harvard research institution, was an abiding satisfaction to Davis and incidentally freed him for other enterprises.

The superbly designed and executed "Elementary Meteorology," for many years the best college text on the subject and still valuable in spite of the enormous increase of meteorological data since 1894, illustrated its author's skill in compiling the best of the world's thought about the physics of the atmosphere and contained the results of his own direct observations. With the help of volunteer assistants he carried on such field investigations as could be prosecuted in New England. The results were published in papers on thunderstorms, the sea breeze, atmospheric convection, and theories of rainfall. Other papers with novel points of view were published on tornadoes, secular changes of climate, and the wind systems of the oceans. His writings on thunderstorms and the sea breeze are "classic" for teachers of meteorology. Between 1884 and 1893 he published forty papers on this general subject.

Work in Geology

Not long after Davis became associated with the inspiring Shaler, the two men published jointly a handsome volume "Illustrations of the Earth's Surface" (1881), intended to popularize

some of the more dramatic and better understood processes that mold the surface of our planet. But the young instructor knew full well that effective, authoritative teaching of geology, the principal subject of his first instructorship, demanded close personal touch with Nature. To get such experience he selected for field study in detail the Triassic formation of New England and New Jersey. On those regions he published fifteen preliminary papers (1882-1896), and a monographic summary of most of his results in "The Triassic Formation of Connecticut" (1898). This gave the first full account of the Triassic volcanic history of the region, announced criteria for proving the extrusive character of some of the "trap sheets" and the intrusive character of others. He also showed how the analysis of topographic forms could be used in explaining the underground, invisible structures of Connecticut and similarly faulted areas of the earth's crust.

While working on the complex history of the Triassic areas, Davis interpolated field investigations: in Columbia County, New York, and the Catskills, where he described the northward continuation of the Appalachian structure; on the glacially-formed drumlins of New England and other regions; on the structure and origin of glacial sandplains and eskers; and on the geological history of Mount Desert Island. In later years he studied: the origin of the thick and widespread Tertiary formations of the Rocky Mountain region, showing that these are not lake beds, as had been generally assumed, but are fluviatile and alluvial-fan deposits; the origin and erosional history of the Basin Ranges of the West; the development of the Colorado Canyon; the mechanical conditions leading to the formation of limestone caverns; and the nature of geological proof, asking geologists "how do you know you are right?"—a question that illustrated the fact that he was as much concerned with the method of scientific thinking as he was in the majestic happenings of earth history. Yet Davis must have been conscious that he made a principal contribution to the philosophy of geology itself. His major contribution to earth science was the conception of the "erosion cycle." He applied it to the

physiographic history of Pennsylvania, New England, the Rhine province, Turkestan, and many other, once-lofty ranges of mountains and proved that each of these regions had been reduced by slow denudation to a lowland, to an "almost-plain" or "peneplain." He further showed that after completion of a cycle, many an "old-mountain peneplain" was uplifted and again deeply dissected by its rivers. With such demonstrations, phrased in the terms of his new geographical vocabulary, Davis made more vivid than ever before the enormous length of geological time. No geologist who had carried the logic of the erosion cycle into the interpretation of the major "unconformities" visible in the strata of the earth's crust was greatly surprised when, later, the results of radioactivity in rocks gave a minimum age of about two billion years to that crust.

Work in Geography

Davis gave much thought to the question as to the content of scientific geography, a subject which, because of the world-wide problems of both war and peace, is likely to be in long-continued demand in our colleges and universities as well as in secondary schools. In the first yearbook of the National Society for the Scientific Study of Education (1902) he wrote:

"Geography as a mature subject is capable of a higher development than it has yet reached. In this connection it will be well to review briefly the three stages of development recognizable in the progress of our venerable subject. Until within about a hundred years the content of geography consisted of a body of uncorrelated facts concerning the earth and its inhabitants. The facts were described empirically, and as a rule very imperfectly. Their location was noted, but their correlations were overlooked; it had not indeed been clearly made out that correlations existed. This blindly inductive first stage was followed by a second stage, which was opened by Ritter's exposition between the earth and its inhabitants; . . . such relationships as were noted had to be explained on the old doctrine of teleology—the adaptation of the earth to man—instead of on the modern principle of evolution—the adaptation of all the earth's inhabitants to the earth. It is this principle which characterizes the third stage of progress, and along with it goes a principle of almost equal importance; namely, that all the items which enter into the relation between the earth

and its inhabitants aid so powerfully in observing and appreciating the facts of nature." . . .

"Geography has today entered well upon its third stage of progress. The 'causal notion' is generally admitted to be essential in the study. . . . Thus understood, geography involves the knowledge of two great classes of facts: first, all those facts of inorganic environment which enter into relationship with the earth's inhabitants; second, all those responses by which the inhabitants, from the lowest to the highest, have adjusted themselves to their environment. The first of these classes has long been studied as physical geography, although this name has been used as a cover for many irrelevant topics. In recent years there has been a tendency to compress the name into the single word 'physiography.'

"The second of the two classes of facts has not yet reached the point of being named, but perhaps it may come to be called ontography. Ecology, to which increasing attention is given by biologists, is closely related to what I here call ontography, yet there is a distinction between the two, in that ecology is concerned largely with the individual organism, while ontography is intended to include all pertinent facts in structure, physiology, individual, and species.

"Neither physiography nor ontography alone is geography proper, for geography involves the relation in which the elements of its two components stand to each other. Each of the components must be well developed before geography can be taken up as a mature study."

Davis held that "teachers of geography should be better taught"; that the subject should be treated more scientifically both here and abroad; that it is far more than the "location of things"; that emphasis on principles rather than on items cannot fail to foster the "intelligence as well as the memory" of pupils in secondary schools; that even in such schools the causal notion should be stressed—"how" and "why" as well as "where" and "what," about things as we find them. "Elementary geography may still deal with the salient facts and place man conspicuously in the foreground; more advanced geography may include examples of greater complexity, by always selecting important rather than trivial matters; but the investigator must study the trivial items along with the greater ones, and all must be duly scrutinized, described, and classified."

The delay of the subject to reach mature treatment did not surprise Davis, who regarded it as "perhaps the most complex of all sciences." Although he did not mention it, not the least of the complications in human geography is man's free will, so often obscuring his responses to physiographic controls. Thus for more than one reason Davis himself did comparatively little in illustrating his fundamental principle of relationship between organisms and environment. He wisely restricted himself to spade work on the inorganic side of the vast subject.

In his chosen field Davis worked on the principle that, while geology is the study of the past in the light of the present, physiography is the study of the present in the light of the past. The one science complements the other and it is no accident that his influence on geological research has been at least as great as his influence on geographical research.

On many occasions he told of his deeply-felt indebtedness to American geologists, particularly Lesley, the staff of the Geological Survey of Pennsylvania, and Powell, Gilbert, Dutton and Holmes of the great western surveys. It was while reading their published writings that "geography gained a new interest" for Davis. That interest culminated in the development of his most famous idea, that of the "cycle of erosion." He visualized a structural unit in the terrestrial landscape and then deduced the topographic results of erosion of this unit by rivers born on its original surface or developed on the unit during the later, systematic evolution of its river system.

"The sequence of forms assumed by a given structure during its long life of waste is determinate, and . . . the early or young forms are recognizably different from the mature forms and the old forms. A young plain is smooth. The same region at a later date will be roughened by the channeling of its larger streams and by the increase in number of side branches, until it comes to 'maturity,' that is to the greatest variety or differentiation of form. At a still later date the widening of the valleys consumes the intervening hills, and the form becomes tamer, until in 'old age' it returns to the simple plain surface of 'youth' " (*National Geographic Magazine*, vol. 1, 1888, p. 15).

In another place he wrote:

"In whatever way a new mass is offered to the wasting forces, let us call the forces that uplift it constructional forces; and the forms thus given, constructional forms. Let all the forces of wasting be called destructional forces; let the sea-level surface, down to which a sufficiently long attack of the destructional forces will reduce any constructional form, be called the ultimate baselevel; and let the portion of geological time required for the accomplishment of this task be called a geographical cycle. Construction, destruction, baselevel and cycle are our primary terms." (*Journal of Geology,* vol. 2, 1894, p. 72.)

It should be noted that "cycle" is here used in the figurative sense of a long period of time. The "plain" of extreme old age could never attain the form of the youthful stage, the greatly multiplied branches of the master rivers and also the interstream areas having individual slopes quite different from the general slope of the young plain, both in magnitude and azimuth. Thus at the ultimate stage of development of the ideal cycle we have an almost-plain with a relief which, though gentle, is vastly more varied than the relief of the young plain. To this final form Davis gave the name "peneplain," which, like "cycle," has won a permanent place in the vocabulary of physiographers and geologists.

Similarly, Davis worked out the ideal cycle as a means of vividly describing the erosional changes suffered by terranes of much greater variety of initial relief, such as mountain ranges and volcanic provinces. With sufficient study any actual unit of the earth's topography can be interpreted in terms of the erosion cycle, with its three dominating ideas, structure, process, and stage.

Nevertheless Davis knew well that the scheme of a simple cycle can rarely suffice for a full scientific description of land forms. He saw that at any stage of its history a topographic unit may be affected by uplift or subsidence, with corresponding effect on the power of eroding streams and on the fashioning of reliefs. Thus the deductive scheme was enlarged to the conception of multiple cycles, separated by "interruptions" due to changes of level. Then, too, the landscape in question may

have had its drainage system affected by change of climate or by volcanism—complications to which he gave the technical name "accidents."

In the Proceedings of the American Philosophical Society (1902) Davis further explained his mode of thought as teacher and investigator in the following words:

The geographer "must generalize in order to bring the observable items within the reach of descriptive terms, and as soon as he generalizes, the use of idealized types is practically unavoidable. Such types have long been in current use, but they have been too few and too empirically defined for the best results. They need to be greatly increased in number, and at the same time they must be correlated with structure, process, and time; for only by following the path of nature's progress can we hope to store our minds with types that shall imitate nature's products. It may be fairly urged that the larger the store of types a geographer possesses, and the more careful and numerous the comparisons with nature by which the types have been rectified, the better progress can the geographer make in new fields of observation.

"But the geographer who adopts the explanatory methods in a whole-souled fashion will find himself called upon not only to imagine a large series of type forms; he must also call into exercise his deductive faculties and employ them to the fullest, if he would make the best progress in the newer phases of his subject, however purely inductive he has imagined it to be. In setting up a store of types, there is need of deducing one type from another at every step; and it may be confidently urged that whoever hesitates to recognize this principle will fail of his effort to describe through explanation. But as a matter of fact, geography has some time been more deductive than geographers have supposed it to be; and the newer phase of the science is not characterized so much by introducing deduction for the first time, as by insisting on its whole-souled acceptance as an essential process in geographical research.

"It is only by giving the fullest exercise to the faculties of imagination and deduction that the cycle of erosion becomes serviceable. Here the geographer who hesitates is lost. . . .

"Thus comparing the partial view of the landscape, as seen by the outer sight, with the complete view of the type as seen by his inner sight, [the geographer] determines, with great saving of time and effort, just where his next observations should be made in order to decide whether the ideal type he has provision-

ally selected fully agrees with the actual landscape before him. When the proper type is thus selected, the observed landscape is concisely and effectively named in accordance with it; and description is thus greatly abbreviated."

As he put the case in 1894, "one of the chief aids to sharp outsight is clear insight." To illustrate, he cited the need of special training for the maker of topographic maps.

"Even the best surveys are necessarily sketched in great part; and the topographer must appreciate his subject before he can sketch it. He must have a clear insight into its expression; his outer eye must be supplemented by his inner eye." . . . Let us therefore strive to complete a deductive geographical scheme . . . until it shall at last be ready to meet not only the actual variety of nature, but all the possible variety of nature."

Davis gave still another summary of the method he recommended to the geographer who aspired to be truly scientific. The savage may do little more than observe natural happenings. The barbarian may go a step further and invent hypotheses in explanation of those events; although his hypotheses are generally wild, he may be said to have a two-faculty approach to Nature. The modern, well-trained naturalist takes four steps. He observes, invents, deduces, and verifies; he deduces the consequences of each hypothesis and then goes back to Nature to improve his deductive scheme and to verify the correct hypothesis if he has been fortunate enough to create it. He has the four-faculty approach to Nature. Two generations of workers in earth science have benefited by Davis's insistence on the value of multiple hypotheses, even "outrageous" hypotheses, in search for the truth about the outdoor world. By such thinking all around the subject, that is, by inventing all of the more reasonable, conceivable solutions to the problem at issue, the investigator is put on the alert. His field record becomes automatically charged with crucial observations and kept free from a load of hit-or-miss, unessential observations. Valuable as it is, the scheme of the erosion cycle is not so important for research in earth science as the underlying philosophy, which makes deduction no whit inferior to induction in the tool-chest of the naturalist.

It seems equally clear that the application of Davis's method of thinking about land forms is of great worth in the training of young students. That method is based on the exercise of the imagination, the highest faculty of the mind; it is the faculty of seeing things as they are and not as they appear to be. To develop it in the youth of school and college is the most precious privilege of the teachers, and for this purpose few high school subjects are comparable with the evolutionary treatment of landscapes.

In 1889, five years after his first announcement of the cycle idea, Davis published the most remarkable of all of its many applications. The subject of this study is entitled "The Rivers and Valleys of Pennsylvania." In this masterpiece of acute reasoning and close observation in a complicated terrane he traced the influence of a whole set of differing geological structures on the development of highly varied land forms and of the associated river system. The results of this path-breaking research make this early paper a classic, the conclusions of which stand fast after more than half a century has added to our knowledge of the Pennsylvanian region.

Other broad units of the earth's relief were similarly treated in scores of later papers. At first their author went into the more easily accessible fields which were already covered by reasonably accurate topographic maps: for example, northern New Jersey, southern New England, and Virginia. Then, as a result of many visits to Europe and travels in central Asia, South Africa, Australia, and New Zealand, he tested, far and wide, his art of describing land forms genetically, in terms of structure, process and stage. As he himself expected, he found new complications, but none that could not be fitted into the general scheme, so long as each individual region is affected by the normal climate. Arid regions, however, demanded different treatment, and, aided by the writings of Passarge and others, Davis worked out a scheme for "the desert cycle." His personal inspection of the great topographic changes wrought by mountain glaciation in central France, the Alps, Norway, and our western Cordillera led him to an incomplete but illuminating

version of a "glacial cycle," this to include evolutionary stages quite different from, though in some instances analogous to, the systematic stages demonstrated in regions exposed to normal climatic conditions. From his field studies of the New England and other coastlines, supplemented by examination of large-scale maps of continental and island shores the world over, Davis aided by his pupil, F. P. Gulliver, showed how shoreline forms can be systematized and scientifically described in the terms of the "cycle of marine erosion."

Two masterly, advanced courses in physical geography, one on the United States and the other on Europe, claimed the unfading admiration of those who listened. Illustrated with a host of large-scale topographic maps of States and European countries, these lectures showed the solid worth of Davis's philosophy, though in scholarly fashion he gave full weight to the opinions and methods of other investigators on the two continents. Probably because of the difficulty of adequately reproducing the maps around which the discussion centered, the material of these unique lectures was never published. To spread his gospel Davis relied chiefly on what he used to call "the rapid-fire gun," propagandizing with hundreds of papers, a number of which were written in French and German and printed in Europe. To the teachers in secondary schools he offered his elementary "Physical Geography" (1898) and a second book, "Practical Exercises in Physical Geography" (1908), but the only comprehensive statement of his matured philosophy was published in German with the title "Die Erklärende Beschreibung der Landformen" (1912). In English we have a convenient assembly of twenty-six among the more important papers dealing with methods of teaching geomorphology and with the general idea of the erosion cycle. This volume of nearly 800 pages was edited by the late Douglas W. Johnson, fellow member of the National Academy of Sciences, with the title "Geographical Essays" (1909).

Not the least merit of Davis's papers and books is their profuse illustration with block diagrams, which tell his story with extraordinary clarity and conciseness. His sureness of pen-

stroke and his sense of values in selecting the essential features of the thousand landscapes he pictured entitle him to the name artist. In this art no geographer nor geologist has ever rivaled him. Everyone who saw him do it marvelled at his simultaneous use of both hands when drawing block diagrams on the blackboard—with amazing speed and practically without erasures.

In 1912 Davis resigned from the professorship of geology which he had held for thirteen years, after having been Harvard's leading geographer for fourteen years. Thus for nearly thirty years he had been a bridge-builder between the two sciences. It was natural that he should be attracted to the problem of coral reefs, which is obviously in the border field. In 1914 a grant from the Shaler Memorial Fund of his university enabled him to visit many islands in the Fiji, New Hebrides, Cook, Loyalty, and Society groups as well as Oahu, New Caledonia, and a long stretch of the Queensland coast inside the Great Barrier Reef of Australia. In 1923 he added to his field experience by travel among the reef-bearing islands of the Lesser Antilles. For twelve years his time was largely spent on the study of his own observations, of the multitude of island charts issued by the hydrographic offices of the world, and on the voluminous literature on the controversial subject of reef origin. At intervals he published the results of his correlations, producing twenty-eight papers and a book on the Antilles. In 1928 there appeared his weighty monograph, entitled "The Coral-Reef Problem," giving his complete views concerning the relative merits of the many hypotheses which have been offered as solutions to the reef problem.

Davis was fascinated by the beauty and apparent cogency of the Darwin-Dana view that atolls and barrier reefs are best regarded as the products of slow subsidence of the foundations on which these structures are built, and at first (1915) thought the subsidence hypothesis to be alone competent in explanation. Later he accepted the idea of "Glacial controls" as useful in accounting for the "platform foundations" and crowning reefs in the marginal areas of the earth's coral-reef zone. His treatment of the problem was dominated by the double principle of deduc-

tion and verification, but in the opinion of the present writer Davis failed to give adequate consideration to some of his premises, including the geological dates when the reef foundations were prepared and when the wave-resisting species of corals became abundant in the tropical ocean. Nor was sufficient attention paid to the relatively enormous areas and remarkable flatness of the lagoons inside atoll and barrier reefs—features which are almost universal and not to be expected on the Darwin-Dana hypothesis. It may further be remarked that this hypothesis is not supported by the findings at test bore-holes in Bermuda and at Michaelmas Cay and Heron Island inside the Australian Great Barrier Reef.

Notwithstanding such failure to secure the premises on which the author of "The Coral-Reef Problem" based his own conclusions, this book will long remain the Bible for geologists and geographers who need a richly illustrated handbook summarizing the facts known about these marvelous structures of the coral seas, or are interested in the relation of the reef controversy to the fundamental question as to the strength and stability of the earth's crust.

Personal Characteristics

Davis had a wonderful capacity for continuous labor. Great physical endurance helps to explain his keen zest for life as well as his success in systematizing a world-embracing science. It took zeal and courage to attempt wholesale reform of the geography taught before his time; both qualities were confirmed as he saw his heresies become gradually accepted principles. His favorite tool was logic. Although at heart he was capable of deep emotion, he would rarely allow emotion to appear in his writings or in his college lectures. Partly for this reason the writings did not appeal to the general public, nor the lectures to the rank and file of Harvard students. Davis was sometimes severely critical of student or colleague who, in order to lighten style of presentation, used simile, metaphor, or other figure of speech which could in the least obscure orderly expression of the thought. Rigorous with himself, he was rigorous

with his students. He detested sloppiness and made disciplined thought and precision the outstanding aims of his courses in both college and graduate school. Yet he was sympathetic with honest endeavor and spent much time and energy helping special students who through no fault of their own, had not been properly prepared for imaginative and logical attack on scientific problems.

By his Quaker upbringing Davis was endowed with a high ethical standard. As we have already noted, his family was forced to leave the Society of Friends, but Davis kept one concrete relic of that early association. Even into old age he addressed each member of his own family with the pronoun "thee." Perhaps this habit of speech was rooted so deeply because of a scene witnessed during his plastic childhood. Then he heard a Quaker boy, fighting with another boy who was not of the Friends, intersperse his blows with the taunt: "Thee little You, thee!" The influence of his forbears was particularly shown in Davis's craving for fairness and justice in the world and in his religious tolerance. He used to say: "Who am I to 'tolerate' anybody's belief? I want to respect it even if I cannot agree." He affiliated himself with the Unitarian church. Two months after his death his last paper, "The Faith of Reverent Science," was published. He there declared his ideal for the human race—progress ever upward "to a truly Christian standard."

KEY TO ABBREVIATIONS USED IN THE BIBLIOGRAPHY

Am. Ac. Pr. = American Academy of Arts and Sciences Proceedings
Am. Assn. Pr. = American Association Proceedings
Am. Assn. Adv. Sc. Pr. = American Association for the Advancement of Science Proceedings
Am. G. = American Geologist
Am. Geog. Soc. Bull. = American Geographical Society Bulletin
Am. Geog. Sp. Pub. = American Geographical Special Publication
Am. Geophys. Tr. = American Geophysical Union Transactions
Am. J. Sci. = American Journal of Science
Am. Met. J. = American Meteorological Society Journal
Am. Nat. = American Naturalist
Am. Ph. Soc. Pr. = American Philosophical Society Proceedings
An. Rep. Astron. Obs. Harvard Coll. = Annual Report of the Director of the Harvard Astronomical Observatory
An. Géog. = Annales de Géographie
Assn. Am. Geog. An. = Association of American Geographers Annals
Atl. Mo. = Atlantic Monthly
Biog. Mem. Nat. Acad. Sci. = Biographical Memoirs, National Academy of Sciences
Boll. R. Soc. Geog. = Bollettino Royal Società Geografica
Boston Soc. N. H. Pr. = Boston Society of Natural History Proceedings
Brit. Assn. Adv. Sci. Rep. = British Association for the Advancement of Science Report
Bull. Volcanologique = Bulletin Volcanologique
Calif. J. Mines and Geol. = California Journal of Mines and Geology
Conn. Sch. Doc. = Connecticut School Document
Ed. Rev. = Educational Review
Eng. Mo. J. = Engineers Monthly Journal
Franklin Inst. J. = Franklin Institute Journal
Geog. Anzeiger = Geographischer Anzeiger
Geog. J. = Geographical Journal
Geog. Rev. = Geographical Review
Geog. Soc. Phila. Bull. = Geographical Society of Philadelphia Bulletin
Geog. Teacher = Geography Teacher
G. Assn. Pr. = Geologists Association Proceedings
G. Mag. = Geological Magazine
G. Rundschau = Geologische Rundschau
G. Soc. Am. Bull. = Geological Society of America Bulletin
G. Soc. Am. Pr. = Geological Society of America Proceedings
Ges. Deutsch. Naturf. u. Ärtze = Gesellschaft Deutscher Naturforscher und Ärtze
Ges. Erdk. Berlin Zs. = Gesellschaft Erdkunde Berlin Zeitschrift
Goldthwaite's Geog. Mag. = Goldthwaite's Geographical Magazine

Harvard Coll. Mus. C. Z. Bull. = Harvard College, Museum of Comparative Zoology Bulletin
Harvard Grad. Mag. = Harvard Graduates' Magazine
Int. Cong. Geol. C. R. = International Congrès Géologique Compte Rendu
Internat. Wochenschr. = Internationale Wochenschrift für Wissenschaft Kunst und Technik
J. Franklin Inst. = Journal of the Franklin Institute
J. G. = Journal of Geology
J. Geog. = Journal of Geography
J. N. E. Waterworks Assn. = Journal of New England Waterworks Association
J. Sch. Geog. = Journal of School Geography
Johns Hopkins Univ. Cir. = Johns Hopkins University Circular
Liverpool G. Soc. Pr. = Liverpool Geological Society Proceedings
Mass. St. Bd. Educ. Ann. Rep. = Massachusetts State Board of Education Annual Report
Meriden Sci. Assn. Tr. = Meriden Scientific Association Transactions
Meteorologische Zeit. = Meteorologische Zeitschrift
Mo. Wea. Rev. = Monthly Weather Review
Nat. Acad. Sci. Pr. = National Academy of Sciences Proceedings
Nat. Geog. Mag. = National Geographic Magazine
Nat. Geog. Mon. = National Geographic Monograph
Nat. Herbart Soc. = National Herbart Society
Nat. Hist. = Natural History
Nat. Research Council = National Research Council
Pan-Am. Geol. = Pan-American Geologist
Pan-Pac. Sci. Cong. Pr. = Pan-Pacific Scientific Congress Proceedings
Pop. Sci. Mo. = Popular Science Monthly
Proc. New Eng. Met. Soc. = Proceedings New England Meteorological Society
Quart. J. Geol. Soc. London = Quarterly Journal of the Geological Society of London
Quart. J. Royal Met. Soc. = Quarterly Journal of the Royal Meteorological Society
R. I. Ed. Pub. = Rhode Island Educational Publication
Roy. Geog. Soc. J. = Royal Geographical Society Journal
San Diego Soc. Nat. Hist. Tr. = San Diego Society of Natural History Transactions
Science = Science
Sci. Mo. = Scientific Monthly
Sci. Prog. = Science Progress
Scottish Geog. Mag. = Scottish Geographical Magazine
Tr. Edin. Geol. Soc. = Transactions of the Edinburgh Geological Society
Tr. N. Z. Inst. = Transactions of the New Zealand Institute

U. S. Dept. Ag. Wea. Bur. Bull. = United States Department of Agriculture Weather Bureau Bulletin
U.S.G.S. Ann. Rep. = United States Geological Survey Annual Report
Van Nostrand's Eng. Mag. = Van Nostrand's Engineering Magazine
Ver. Erdk. Leipzig Mitt. = Verein für Erdkunde Leipzig Mitteilungen
Wash. Acad. Sci. J. = Washington Academy of Sciences Journal

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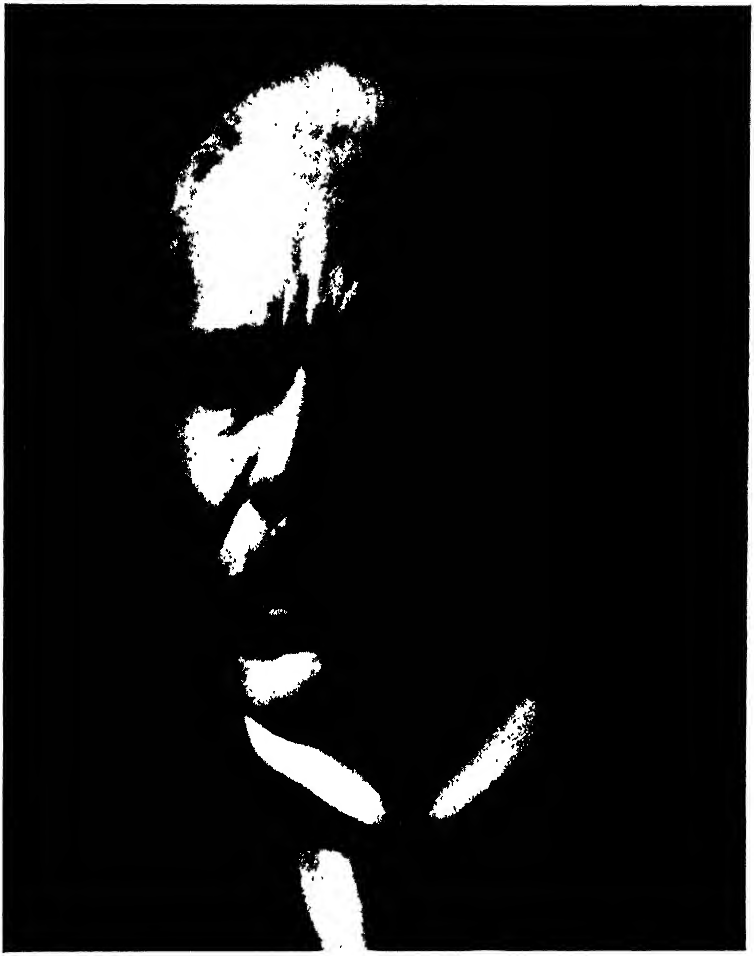

Aleš Hrdlička

NATIONAL ACADEMY OF SCIENCES

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BIOGRAPHICAL MEMOIRS
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BIOGRAPHICAL MEMOIR

OF

ALEŠ HRDLIČKA

1869–1943

BY

ADOLPH H. SCHULTZ

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1944

ALES HRDLICKA

1869–1943

BY ADOLPH H. SCHULTZ [1]

Aleš Hrdlička was born on March 29th, 1869 in the town of Humpolec in Bohemia where his parents and grandparents on both sides had been born and reared. The paternal grandfather was by profession a cloth-maker. Maximilian Hrdlička, the father of Aleš, was a cabinet-maker. He married Karolina Wagner, the daughter of a cabinet-maker, in 1870 and they had five sons and two daughters, Aleš being the first-born.

Aleš entered the local school in his seventh year and passed to the public highschool in his twelfth. Soon afterwards (1882) he emigrated with his father to America to found a new home in New York to which the other members of the family followed later. For the next six years Aleš worked in a cigar factory and attended nightschool. At the age of nineteen he contracted typhoid fever and was attended during his long illness by Doctor M. Rosenbleuth, a former rabbi who took a great interest in his young patient and urged him to obtain a medical education. As a trustee of the Eclectic Medical College of the City of New York, Dr. Rosenbleuth gained Aleš' admittance to this institution and also acted as his preceptor. From this school Aleš graduated in 1892 with the highest grades in his class. Immediately he began to practice medicine and quickly became physician to several organizations on the East Side. At this time he also enrolled as a student in the New York Homeopathic Medical College, attending classes and clinics in the daytime and taking care of his practice largely at night. In 1894 he graduated from this Homeopathic College, again leading his class, and shortly thereafter passed a State Board examination (Allopathic) in Baltimore, intending to apply for a position in the Johns Hopkins Hospital. At this time,

[1] The writer is indebted to Dr. T. D. Stewart, the successor of Dr. Hrdlička at the U. S. National Museum, for much of the information contained in this biography and, particularly, for having completed the accompanying bibliography. The latter had already been collected to 1939 in a paper by Dr. Stewart which had appeared in the American Journal of Physical Anthropology, volume 26, 1940.

however, he was offered an internship at the new State Homeopathic Hospital for the Insane at Middletown, New York, which he accepted. Hrdlička's anthropometric interests can be traced to this decisive stage of his development. In one of his earliest publications, dated 1895, he had already introduced bodily measurements on one thousand individuals, grouped according to sex and form of insanity.

In 1895 Hrdlička was offered the position of Associate in Anthropology at the newly organized Pathological Institute of the New York State Hospitals. This appointment he accepted with the condition that he be permitted first to visit European laboratories to become better acquainted with certain fields of science. At his own expense he went to Paris early in 1896 and for four months he studied anthropology under Manouvrier, physiology under Bouchard and medico-legal subjects under Brouardel, besides attending clinics at various hospitals. He also travelled to Germany, Switzerland, Austria, Belgium, and England to inspect medical and anthropological institutions. In September of 1896 he returned to New York to begin his work at the Pathological Institute. This is also the date of his marriage to Marie Strickler Dieudonnee, a young French woman who had earlier attended some of his lectures. With her he had a happy and devoted, though childless, married life until her death in 1918. In 1920 he married Mina Mansfield, who survives him.

Undoubtedly influenced by his recent European contacts, Hrdlička developed in his new position at the Pathological Institute an ambitious program for detailed bodily measurements in large series of inmates of state institutions and for the systematic collection of human skeletons and autopsy material. Through his energetic efforts and with the aid of collaborators, he had specially trained, records rapidly accumulated, especially those appertaining to the body form of largely abnormal individuals. These data, unfortunately, were later lost through fire. As early as 1897 Hrdlička began to realize the lack of adequate comparable data on the body build of normal persons and the great need of such information. The subsequent search

for opportunities to collect accurate records on the proportions of the outer body and the skeleton of normal man became a great influence in his career. Professor G. S. Huntington had started a collection of human skeletons at the anatomy department of the College of Physicians and Surgeons in New York which at that time was unique in this country. Hrdlička not only studied this material in detail, but assisted in augmenting it and began in 1898 to use it as a standard for his later comparisons with skeletons of other races. In the latter year he received an invitation to accompany Carl Lumholtz to Mexico to be in charge of medical and anthropometric work among the Indians to be studied on that expedition and in order to have an opportunity to investigate a "normal" population. This was Hrdlička's initiation into field-work and the first of his many later trips for the collection of material and data appertaining to the races of man. Upon his return from Mexico in 1899 he resigned from the Pathological Institute, which was having great administrative and financial difficulties, and accepted an offer to carry on his work in medical and physical anthropology on expeditions for the American Museum of Natural History under the general direction of Professor F. W. Putnam. Thus, until 1902, he visited yearly the Indians of the southwestern United States and northern Mexico and managed to issue an already very imposing list of publications, dealing now chiefly with anatomical and anthropological observations. During this period Hrdlička had become acquainted with Professor W. H. Holmes, then head curator of anthropology in the National Museum at Washington and soon after chief of the Bureau of American Ethnology. In those days all human skeletal material received by the Smithsonian Institution was stored in the Army Medical Museum, where it could not be adequately cared for nor readily studied. To Professor Holmes and others it seemed most desirable to transfer these collections to the National Museum and to place an expert in charge of them. In the spring of 1903 there was established at the National Museum a division of physical anthropology and on May 1st of that year Hrdlička was appointed "Assistant Curator in Charge" of this new section which

then occupied a small space in one of the galleries of the old Museum building. With Hrdlička's prodigious energy and rare talents for collecting and utilizing new material his division developed at a rapid rate and in 1910 he was advanced to a full curatorship. The history of the first forty years of this division, which to-day is one of the world's few great collections and laboratories of physical anthropology, represents the life-work of Aleš Hrdlička.

In 1905 Hrdlička resumed his field-work on the Indians of the Southwest and Mexico and the following year visited Florida to examine the newly-found remains of supposedly ancient man. In 1909 he was called to Egypt to investigate and collect the numerous skeletons in an early Egyptian cemetery. He used this opportunity also for measuring the predynastic remains, stored in Cairo, and a series of living natives at the Kharga Oasis. On his return he visited Turkey, Greece, Hungary, Russia, and other European countries to become acquainted with the types of humanity to be found there. In 1910 Hrdlička travelled in South American countries, attending the International Congress of Americanists in Buenos Aires and Mexico City, examining remains of alleged ancient man in Argentina, and collecting well over 3000 skulls of Indians in Peru, activities which, as always, led to a large number of publications. In 1912 he was requested to prepare an exhibit in physical anthropology for the Panama-California Exposition, to be held in San Diego in 1915, a commission which was accompanied by a very substantial grant of money. In this way he was enabled to organize a series of expeditions for the collection of new material and data. He himself went by way of Europe to Siberia and Mongolia in 1912, using this opportunity also for a thorough examination of sites and remains of ancient man in the Old World. In 1913 Hrdlička made his second trip to Peru and in 1916 to Florida, again collecting new material and information on American aboriginals. During all these years he persisted in measuring samples of the white population of the United States, limiting his selection to individuals whose ancestors on both sides had been born in the United States for at least two generations.

This enormous undertaking, comprising complete records on nearly a thousand individuals, resulted finally (1925) in his book *The Old Americans,* which supplies standard measurements for normal whites and thus forms a basis for comparative work.

In 1920 Hrdlička accepted an invitation by the Rockefeller Foundation to give a series of lectures at the Peking Union Medical College. Thus he was enabled to visit Hawaii, Japan, Korea, Manchuria, and northern China, countries teeming with anthropological interest. In 1922 he went to Rio de Janeiro as chairman of the American delegation to the International Congress of Americanists, after which he travelled extensively in Europe to study the latest discoveries of early man. The following year he returned to Europe as director of the American School of Prehistoric Studies, in which capacity he could reëxamine a great many of the important finds of fossil man. During the greater part of 1925 he visited India, Ceylon, Java, Australia, South Africa, and Europe, collecting data on the skulls of Negroes, Australian aboriginees and the extinct Tasmanians. He also investigated the site of the find of Rhodesian man.

In 1926 Hrdlička began his anthropological surveys in Alaska, which became his foremost interest for the remainder of his life. The series of his many trips to the far North was interrupted in 1927 by an invitation to deliver the Huxley Memorial Lecture before the Royal Anthropological Society of Great Britain. On this occasion he again visited various countries on the European continent to complete preparations for his comprehensive work on *The Skeletal Remains of Early Man.* Between 1929 and 1938 Hrdlička went for nine summers to Alaskan rivers, the Aleutian Islands and Kodiak and Commander Islands. He measured the living Aleutians, Indians and Eskimos encountered and excavated and collected enormous skeletal series of these races. Among the inhabitants he became known as the "skull doctor" and he readily gained local cöoperation in most cases. With these pioneering activities he successfully developed his broad thesis of the Asiatic origin of the American aborigines. For further support of the latter sound view he had long planned

a special trip to Siberia. In 1939, at the age of seventy years, he was finally enabled to realize this culminating chapter of his great program. Upon reaching London in April he suffered an attack of coronary thrombosis from which he made a remarkable recovery, whereupon he delivered two lectures and examined the ancient human remains from Palestine at the Royal College of Surgeons. Later that year he courageously continued his trip to Russia and even to Siberia. He visited all important museums where he measured large series of skulls of many Siberian tribes and investigated newly unearthed remains of a Neanderthal child as well as many neolithic skulls in various collections. This was the last of Hrdlička's many trips to nearly all parts of the world. His remaining years he spent in Washington in the midst of his enormous collections, fully occupied with recording and publishing experiences and observations from a lifetime filled with ceaseless work. Early in 1943, feeling perfectly strong again, he began plans for a trip to the highland Maya of Guatemala, but late in August he became ill. On September 5th, 1943, when in his 75th year, he died of a heart attack at his home in Washington.

The growth of physical anthropology during the past half century and, particularly, its rise in the United States has greatly benefited by the labors of Aleš Hrdlička. He has published a larger number of contributions to this science than has anyone else. He lived for his chosen field to which he gave all of his time and exceptional energy. His work was his hobby and his only and absorbing ambition was to advance the young science of physical anthropology. This he did accomplish admirably and in many ways. He not only added constantly to the stock of our knowledge with the great mass of his publications, but created one of the world's largest collections of research material for physical anthropology, containing at his death well over 15,000 human skulls or skeletons besides large series of other specimens. He improved and helped to unify the methods of investigation and promoted directly and indirectly the needed clarification of the aims and scope of physical anthropology. Last, but not least, he founded and managed a special journal

and organized, and for some years presided over, a society of physical anthropologists, thus vitally helping and stimulating his fellow scientists in this country.

Hrdlička's outstanding and lasting contributions to anthropological knowledge are centered around his following three general interests: 1. The detailed investigation and tabulation of the ranges of normal variations in features of the outer body, the skeleton and the teeth among the different races of man, in the two sexes and, to a lesser extent, at different ages. 2. The collection and publication of reliable and adequate data on the somatic characters of the three large divisions of mankind in America, White, Indian-Eskimo and Negro, to provide basic standards for comparisons. 3. The compilation of precise information on all discoveries attributed to early man and critical examination of all evidence of the real nature and antiquity of these findings. The publications belonging to these main categories are all in close accord with Hrdlička's definition and interpretation of physical anthropology as "the study of man's variation" (*Physical Anthropology: Its Scope and Aims.* 1918). In this work he concerned himself properly and exclusively with the primary question: *What* are the variations of man? He left the secondary, though more fascinating, questions, beginning with *how* and *why,* to his successors. As readily seen by the accompanying bibliography, Hrdlička's creative activities embraced a great variety of additional interests which appear to be of lesser magnitude only against the background of his main professional program. Thus he wrote repeatedly on the history of physical anthropology, especially that of America. He paid much attention to some physiological conditions in, particularly, Indians and Eskimos. Anthropometric techniques he discussed in numerous articles and in a book which appeared in two editions. He observed the quadrupedal mode of locomotion in children and published many detailed accounts thereof. He recorded metrically the body build of eminent scientists. Many of his articles deal in part or wholly with ethnological and archaeological objects. Observations on skeletal material of non-human primates play an extensive role in a considerable

number of his publications. This enumeration is quite incomplete, but suffices to indicate the wide range of Hrdlička's scientific interests and the diversity of his studies. As an author he contributed much to the popularization of his science and wrote many non-technical and generalizing articles on man's evolution, human races, racial migrations, the relations between anthropology and other sciences, etc.

When Hrdlička began his full-time work in physical anthropology this science could boast of comparatively few sound observations and facts, derived from really representative series, but of many theories often advanced by inexperienced outsiders. Hrdlička quickly sensed the crying need for far more facts and he seems to have acquired a healthy aversion to unsupported hypotheses and rash speculation. His publications, with few exceptions, are of a purely descriptive nature; indeed, a large share consists of little besides tabulations and catalogues of new data. This was precisely what was most useful during that recent epoch in the history of his still young science and has gone far in helping to lay a solid foundation, on which to build in days to come. In his later years he gradually permitted himself to draw more extensive deductions than in his earlier studies which mostly contain very scanty conclusions. His attitude, when at the height of his career, is indicated by the following quotation from the introduction to his volume of collected data on *The Skeletal Remains of Early Man:* "The accounts to be given are intended to be fairly impersonal. There will be no theory to defend, no side to be taken in any controversy, though there may be suggestions where justified by the general acquaintance with the field and perhaps by the better perspective of one who is not involved in any individual finds or opinions."

In regard to his own conclusions Hrdlička seems to have been rarely plagued by doubts. As he was always loyal to his friends so was he loyal to his own ideas. Painstaking and often hesitant in reaching deductions, he would elaborate them on later occasions, but never contradict them. Thus, once having become convinced that man's arrival in America was of comparatively

recent date, he steadfastly clung to and passionately fought for this conclusion to the end of his life, even in view of evidence demanding a reconsideration of the problem of the antiquity of man in the New World.

Hrdlička was largely a self-taught anthropologist and it is remarkable that he succeeded in learning so much of ethnology, archaeology, geology, etc. while busily engaged in developing his comprehensive research program in physical anthropology. He had a medical education which gave him much, yet lacked much else that would have formed an ideal preparation for his future work in a philosophical science. He had no special training in biology and his schooling in mathematics had not gone beyond elementary instruction. It is probably for these reasons that he paid almost no attention to genetics or to those other old and new branches of biology and comparative anatomy which have acquired great significance for physical anthropology of to-day, and that he would never admit that modern statistical methods have vastly increased our powers for discovering and analyzing the laws of human nature. In conversation with the writer he expressed nothing but scorn for the aims of all recent work on human constitution. Hrdlička lacked the time in his busy life for familiarizing himself with all new developments in his science and his own investigations did not necessarily require all the specialized training, expected of the present generation of physical anthropologists. It was only by his persistent intolerance of certain innovations and advances that Hrdlička may have retarded to a slight extent the more recent development of American physical anthropology which he had always guided with genuine devotion and much effect. In his capacity as editor of the American Journal of Physical Anthropology, Hrdlička persisted in discouraging studies of a statistical nature and under his management morphological papers left very little space for contributions from other fields. It is, nevertheless, this journal which represents in general the most valuable service among the many Hrdlička rendered to physical anthropology, and this in spite of the frequent claim that the journal should and could have been even more influential, had it included all

new interests as fast as they developed. It was Hrdlička who had the vision and courage to found an American journal, devoted exclusively to physical anthropology, in the difficult wartime of 1918. He personally managed all affairs of this journal until 1927, when he turned it over to the Wistar Institute together with a substantial endowment from his private means, and he edited the journal to the completion of the 29th volume in December 1942. The splendid series of these volumes forms a great and lasting monument to the disinterested and faithful labors of its founder and editor.

Hrdlička was a tireless worker all his life; he was never really hurried, yet never idle. To him the world contained so much that should be observed and recorded, that he could feel no temptation to relax. The six weeks in a hospital, following his heart attack in 1939, he called "the first vacation of my life" (*An Anthropologist in Modern Russia.* 1942). He was endowed with great bodily strength and exceptional physical endurance. Even in his advanced years he could still use a shovel most effectively for his Alaskan excavations. He walked a great deal and could easily overtake many a younger man. He scorned overcoats. He once told the writer that at home he kept a board under his bed-sheet, so that he could readily sleep on the ground while on expeditions. He never used tobacco or alcohol and led a rather frugal existence, granting himself no luxuries. Yet few men enjoyed life more intensely than he did. Everywhere and at all times he indulged in his absorbing passion for collecting knowledge and potential new data in form of specimens. To the very last of his field-trips he derived the keenest happiness from every new skull which he could carry back to his boat to be added to the thousands of others he had already amassed at home. Hrdlička's own attitudes and qualities are clearly reflected in his characteristic and touching advice to students contemplating a career in physical anthropology. After recommending a medical education and stressing the need for a good reading knowledge of foreign languages, he demands of the "worker-to-be" that:

"He must have good, enduring eyesight; and large capacity for work both in the field and in the laboratory. Last but not least, he should possess those mental qualities which will enable him to follow his work with undimmed enthusiasm and vigor under smaller material compensation and perhaps other advantages than those of his friends who have remained in medical practice or chosen other vocations; for anthropology is not an industrial necessity. The compensations for this lie in the high grade of his work. He deals intimately with the highest organisms, he contributes to the knowledge of what is most worth while. His studies of human evolution and antiquity, of the developing child and youth, of the infinite variation of full-blown manhood and womanhood, of the laws that control all this, and of the means by which these laws may consciously and effectively be directed for future advance in humanity—all these will provide him with mental food of such an order that he will easily forget the regrets of not having chosen a more remunerative vocation." (*Anthropometry.* 1920.)

Hrdlička made friends easily and could quickly win the confidence of natives. His personality radiated kindliness combined with a charming naïveté. In appearance he was essentially serious, dignified and somewhat picturesque. In conversation he tended to avoid arguments, but loved to bestow well-meant advice in a rather paternal fashion. Hrdlička was a very generous man who not only gave freely of his time to all of his numerous visitors, but also of his slender private means to the cause of his science. Thus he sent vital funds for anthropological research to his native country, particularly to the Charles University in Prague, and thereby greatly helped the splendid work of his colleagues in Czechoslovakia. He contributed financial aid to his own journal and in his will left a large part of his estate for the benefit of physical anthropology.

Hrdlička's work had constantly been encouraged and approved not only by his professional appointments and frequent invitations for foreign travel, but also by many honors which spoke for the high appreciation of his labors. He was elected to membership in the American Philosophical Society in 1918, in the National Academy of Sciences in 1921 and in numerous other eminent societies here and abroad. In 1918 he was chair-

man of section *H* of the American Association for the Advancement of Science. He was a president of the American Anthropological Association (1925-26), of the Washington Academy of Sciences (1928-29) and of the American Association of Physical Anthropologists (1928-32). He was chosen as Huxley Medal lecturer in London in 1927 and as Kober Foundation lecturer of Georgetown University in 1932. He was appointed secretary or delegate to several international congresses and served on the National Research Council as secretary of the committee on anthropology (1917) as well as on a great many committees of learned societies. He received honorary degrees from the universities of Prague and of Brno and for his sixtieth birthday celebration his Czech colleagues issued a Hrdlička Anniversary Volume of their journal *Anthropologie.* On the occasion of his seventieth birthday the American Association of Physical Anthropologists gave him a well-attended testimonial dinner and prepared in his honor an anniversary volume to which 24 of his colleagues from many countries contributed papers.

Aleš Hrdlička has a permanent and honored place in the history of physical anthropology, a science to which he devoted his life with never-failing enthusiasm and energy and with enduring results.

KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

Albany Med. Ann. = Albany Medical Annals.
Am. Anthrop. = American Anthropologist.
Am. Foreign Ser. J. = American Foreign Service Journal.
Am. J. Anat. = American Journal of Anatomy.
Am. J. Insan. = American Journal of Insanity.
Am. J. Phys. Anthrop. = American Journal of Physical Anthropology.
Am. J. Sci. = American Journal of Science.
Am. Mag. = American Magazine.
Am. Nat. = American Naturalist.
Am. Philos. Soc. = American Philosophical Society.
Am. Scholar = American Scholar.
An. Mus. Nac. Mexico = Anales Museo Nacional Mexico.
Anat. Rec. = Anatomical Record.
Anat. Anz. = Anatomischer Anzeiger.
Ann. Rep. Bur. Am. Ethnol. = Annual Report, Bureau of American Ethnology, Smithsonian Institution.
Ann. Rep. Middletown State Homoeop. Hosp. = Annual Report, Middletown State Homoeopathic Hospital.
Anthrop. Anz. = Anthropologischer Anzeiger.
Anthrop. Papers Am. Mus. Nat. Hist. N. Y. = Anthropological Papers, American Museum of Natural History, New York.
Arch. Neurol. Psychopath. = Archives of Neurology and Psychopathology.
Art and Arch. = Art and Archaeology.
Bull. Am. Mus. Nat. Hist. N. Y. = Bulletin, American Museum of Natural History, New York.
Bull. Bur. Am. Ethnol. = Bulletin, Bureau of American Ethnology, Smithsonian Institution.
Bull. N. Y. Acad. Med. = Bulletin, New York Academy of Medicine.
Bull. et Mém. Soc. d'Anthrop. Paris = Bulletin et Mémoires, Société d'Anthropologie de Paris.
Bull. Texas Arch. Pal. Soc. = Bulletin, Texas Archaeological and Paleontological Society.
Bull. U. S. Nat. Mus. = Bulletin, United States National Museum.
Bull. Wagner Free Inst. Sci. Phila. = Bulletin, Wagner Free Institute of Science, Philadelphia.
China Med. J. = China Medical Journal.
Contr. Mus. Am. Indian N. Y. = Contributions, Museum of the American Indian, New York.
Contr. Path. Inst. N. Y. State Hosp. = Contributions, Pathological Institute, New York State Hospital.
Crón. Med. Mexicana = Crónica Medica Mexicana.
Czech. Rev. = Czechoslovak Review.
Dominion Dent. J. = Dominion Dental Journal.

Evol. = Evolution
Explor. Field-Work, Smith. Inst. = Explorations and Field-Work, Smithsonian Institution
Intern. J. Orthod. Dent. Child. = International Journal of Orthodontics and Dentistry for Children
J. Acad. Nat. Sci. Phila. = Journal, Academy of Natural Sciences, Philadelphia
J. Am. Med. Assoc. = Journal, American Medical Association
J. Am. Mus. Nat. Hist. N. Y. = Journal, American Museum of Natural History, New York
J. Dent. Res. = Journal of Dental Research
J. Geol. = Journal of Geology
J. Hered. = Journal of Heredity
J. Nerv. Ment. Dis. = Journal of Nervous and Mental Diseases
J. Roy. Anthrop. Inst. = Journal, Royal Anthropological Institute
Lit. Dig. = Literary Digest
Mag. Daughters Am. Rev. = Magazine, Daughters of the American Revolution
Md. State Dent. Assoc. = Maryland State Dental Association
Med. Rec. = Medical Record
Mem. Nat. Acad. Sci. = Memoirs, National Academy of Sciences
Nat. Acad. Sci. Biogr. Mem. = National Academy of Sciences Biographical Memoirs
Nat. Geogr. Mag. = National Geographic Magazine
N. Y. Med. J. = New York Medical Journal
N. Y. Times Mag. = New York Times Magazine
N. Am. J. Homoeop. = North American Journal of Homoeopathy
Oriental Inst. Publ. = Oriental Institute Publications
Outlook and Indep. = Outlook and Independent
Papers, Peabody Mus. Am. Arch. Ethnol. Harvard Univ. = Papers, Peabody Museum of American Archeology and Ethnology, Harvard University
Proc. Am. Phil. Soc. = Proceedings, American Philosophical Society
Proc. Am. Med. Psych. Assoc. = Proceedings, American Medico-Psychological Association
Proc. Assoc. Am. Anat. = Proceedings, Association of American Anatomists
Proc. Intern. Cong. Amer. = Proceedings, International Congress of Americanists
Proc. Nat. Acad. Sci. = Proceedings, National Academy of Sciences
Proc. Pan-Amer. Sci. Cong. = Proceedings, Pan-American Scientific Congress
Proc. U. S. Nat. Mus. = Proceedings, United States National Museum
Prog. Educ. = Progressive Education

Publ. Eclectic Med. Coll. City N. Y. = Publications, Eclectic Medical College of the City of New York
Publ. Florida State Hist. Soc. = Publications, Florida State Historical Society
Publ. Res. Com. Am. Dental Assoc. = Publications, Research Committee, American Dental Association
Sci. = Science
Sci. Am. = Scientific American
Sci. Am. Suppl. = Scientific American Supplement
Sci. and Invent. = Science and Invention
Sci. Month. = Scientific Monthly
Smith. Misc. Coll. = Smithsonian Miscellaneous Collections
Smith. Rep. = Annual Report, Smithsonian Institution
Smith. Sci. Ser. = Smithsonian Scientific Series
Soc. Res. Child Develop. = Society for Research on Child Development
State Hosp. Bull., N. Y. = State Hospital Bulletin, New York
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Trans. Intern. Cong. Amer. = Transactions, International Congress of Americanists
Univ. Calif. Publ. Am. Arch. Ethnol. = University of California Publications in American Archaeology and Ethnology
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W G MacCallum

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OF

WILLIAM GEORGE MacCALLUM

1874–1944

BY

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PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1944

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William George MacCallum was born in Dunnville, Ontario, Canada, on April 18, 1874. His family had lived many years in that region, for his grandfather, George MacCallum, a Scotchman, born in 1818, had come to Canada as a young man. He settled in the Province of Ontario, married, had five sons and lived to a very old age. The eldest of these sons, born in 1843, was named George A. MacCallum. He studied medicine, married Miss Florence Eakins of Sparta, Ontario, and began his professional work as a general practitioner in the village of Dunnville. He was doctor and surgeon, not only for the village but also for the surrounding country. Natural history seems to have been, at this time, his hobby though later in life zoology became a subject to which he devoted serious attention. Even during the busy days when his practice was most pressing, he found time to collect specimens of various sorts which he arranged in a small museum. There was also a shed that served as a laboratory where specimens could be examined.

It was in this atmosphere that William MacCallum, the second child of George and Florence MacCallum, lived as a boy. First the public school and then the High School of Dunnville furnished him an education which he must have acquired easily, for he was ready for college at 15. It is very likely, however, that he learned quite as much at home as he did at school; for he spent a great deal of time with his father, and was in the habit of driving all over the country with him when Dr. MacCallum visited his patients. He even lent a hand at an operation on occasions when help was needed, though in later years he wondered whether he was actually of much assistance. This pleasant companionship between the boy, William MacCallum, and his father formed the basis of a very close and devoted association that lasted until his father died.

The final three years of school were busy ones, for MacCallum was preparing for college and was deep in the study of English, the classics and mathematics. He entered the University of Toronto at 15 years of age. Greek had a fascination for him. He worked at it during his entire four years at college, but on the advice of his father he also took courses in zoology, chemistry, physics and geology. Partly due to his father's influence, partly stirred by Prof. Ramsay Wright, the biologist at Toronto, he became interested in collecting insects and plants and paid some attention to the study of trematode parasites. MacCallum graduated from Toronto in 1894.

At this point he wished to continue Greek as a life work, but his father was convinced that there was no possible career for him except medicine, and with reluctance he acceded to this point of view and decided to enter a medical school. By some accident he had heard of the Johns Hopkins Medical School and learned that the first class of students had entered in 1893. He applied for admission, and as he had completed at the University of Toronto the equivalent of the first year's work in medicine, he hoped to be allowed to join the students who had entered in 1893. There was some opposition to this proposal by members of the faculty, but he was finally granted permission to enter the second year and thus became a member of the first class of the Johns Hopkins Medical School. He graduated with the degree of M.D. in 1897.

After graduation he spent one year as an intern at the Johns Hopkins Hospital and then became assistant resident in pathology under Dr. William H. Welch. This appointment marked the start of a career in a medical science which absorbed his interest during the remainder of his life.

In 1900 MacCallum went to Germany and worked in the laboratory of Prof. Marchand in Leipzig. Shortly after his return to Baltimore in 1901 he was made resident pathologist, then Associate Professor of Pathology and finally was promoted in 1908 to the position of Professor of Pathological Physiology, a chair created especially for him. In 1909 he accepted a call to Columbia University and from 1909 to 1917 he held the positions

of Professor of Pathology at Columbia University and Pathologist to the Presbyterian Hospital in New York.

The first fifteen years which MacCallum spent in Baltimore furnished him an opportunity to pursue his work under the most favorable circumstances. His research and teaching were carried on in the laboratories over which Dr. Welch presided, and as his position in this department became more and more important, his relations with Dr. Welch grew more and more intimate. There were opportunities, too, for almost daily contact with other men of superior attainments. Osler's interest in pathology was proverbial; Simon Flexner was in the department for a year or two after MacCallum entered it; Thayer was studying malaria, a subject to which MacCallum had already made an outstanding contribution, and an interest in the thyroid and parathyroid glands resulted later in a close association with Halsted, whom he admired extravagantly. Eugene Opie and Harvey Cushing were more nearly of his own age, and there were other contemporaries all working at problems in medicine and busy with teaching. It was a period when there were few distractions, and, as will appear later, one in which MacCallum did much of his best work.

The move to New York in 1909, however, brought many new responsibilities with it. Important developments in medical education were under way at this time in New York, for the College of Physicians and Surgeons of Columbia University and the Presbyterian Hospital were contemplating an affiliation which was expected to lead eventually to a close combination of the two institutions. MacCallum was appointed a member of a Committee of the Medical Faculty to formulate plans for this interesting development. Many hours, therefore, were spent in conferences and much thought was devoted to considering ways and means by which this new venture could be most successfully brought about. It was several years, however, before these early deliberations came to full maturity and MacCallum had left New York long before the great modern structures which house the "Medical Center" had been erected on Washington Heights.

There were other problems of a somewhat different nature

that demanded his attention. Among these was an effort to abolish the coroner system which was then in vogue in New York City. This system he regarded as highly inefficient and undesirable, and proposed to substitute for it a better arrangement. It was largely through his influence and against considerable opposition, that the coroners were replaced by medical examiners who were required to be doctors of medicine, as well as skilled pathologists, and who were selected from the civil service list by competitive examination. The reform was an important one and the system has been adopted by other cities.

It was during this same period of varied and intense activity that MacCallum was persuaded to write a text book of pathology. The work was original in conception for he planned it with the idea of discussing disease, as far as possible, upon the basis of etiology. There was no systematic description of all the abnormal conditions that may affect each organ, but an effort was made to consider the general principles of pathology as illustrated by a study of the commoner and more important diseases. The entire treatise "was constructed," as he pointed out in the preface, "upon the idea that all pathological disturbances are the result of some form of injury or of the immediate or more remote reactions of the body to injury." It was an admirable work and went through many editions; but unfortunately a great deal of his time was occupied in the years that followed the first publication of the book in 1916, by the many revisions that were required by the repeated demand for new editions.

In 1917 Dr. Welch relinquished the chair of pathology at the Johns Hopkins University to assume the directorship of the newly established School of Hygiene and Public Health. MacCallum was chosen his successor and returned to Baltimore in the capacity of Baxley Professor of Pathology in the Johns Hopkins University and Pathologist to the Johns Hopkins Hospital. This second period in Baltimore started as a busy one, for the country was then at war and MacCallum was called upon to act as pathologist on a commission which was appointed to study pneumonia in the Army cantonments. In 1920 the pathological laboratory was destroyed by fire. This necessitated the use of

temporary quarters and MacCallum was plunged into the intricate business of drawing plans for a new building. He became deeply interested in the task and contemplated the possibility of broadening the conventional scope of pathological research, as it had been pursued in most schools of medicine, by extending it to a study of diseases in animals, plants and even fishes. For this purpose a small green-house was constructed near the roof of the building and space for an aquarium was provided. An adequate chemical laboratory was also included in the plan. Ample arrangements were made for all forms of photography, upon which he laid great stress as a method of recording pathological material.

Teaching was one of his major interests and a profession in which he excelled. His methods of approach to the study of pathology were so broad and so varied that they attracted many advanced students to apply for work in his laboratories. An innovation upon which he laid much stress was the collection in separate rooms of pathological material illustrating the alterations occurring during the course of any one of several common diseases, so that small groups of students could concentrate their study upon one disease at a time. There was one room devoted to rheumatic fever, another to tuberculosis and so forth. These isolated collections replaced the conventional museum of pathology and were used constantly for the instruction of students.

Another exercise which proved very stimulating was the clinical pathological conference which he and Dr. Thayer conducted every Wednesday morning at twelve o'clock. Thayer's accurate diagnosis, based on his thoughtful clinical discussion of the cases, was followed by MacCallum's illuminating exposition of the pathological conditions that he had found at autopsy. The room was always crowded with students, members of the hospital staff and visitors who listened with rapt attention to the lively discussions that took place during this exercise.

Neither MacCallum's interest in teaching nor his investigations in science appeared to satisfy his restless mind completely, which seemed almost impatient in its requirements for knowledge, nor did they fulfill altogether his emotional needs which

sought continuously for new experiences. Greek never lost its fascination for him, though curiously enough in all his travels he never appears to have made a journey to Greece. He was an omnivorous reader and, since he was perfectly familiar with both French and German, his knowledge of literature was very extensive. He was fond of music and enjoyed especially hearing both German and French opera.

One pastime in which he frequently indulged was to explore the historical aspects of medicine. Dr. Osler had founded in 1890 the Johns Hopkins Historical Club, of which Dr. Welch was the first president and an enthusiastic supporter; and at its meetings many papers of considerable value were presented by members of the University and Hospital staffs. MacCallum was sometimes among the contributors and thus from the time that he was a student developed a taste for medical history. This led him to acquire from time to time some valuable copies of early medical works, among which was a first edition of Vesalius. He also gathered together a large collection of medical prints which he had framed with appropriate captions and hung upon the walls in the corridors of his laboratory.

Perhaps above all diversions, however, he delighted most in travel. There was almost no country on the face of the globe that he had not visited at one time or another. Europe was thoroughly familiar to him. He studied pathology and heard opera in Germany, learned to bind books during one summer's vacation in Paris, and performed autopsies during another summer in the Ospedale Maggiore in Milan. The West Indies, South America, South Africa, Australia, India, Siam, Japan and the South Sea Islands were all regions that came within the scope of his travels. In Jamaica he investigated an epidemic of alastrim, a mild form of smallpox, and later wrote a monograph on the subject. In Singapore and Rangoon he performed autopsies. In Calcutta he had a severe attack of dengue fever; in the Fiji Islands, Java, Singapore and Kuala Lumpur he studied leprosy; and in the course of his travels he made innumerable photographs in Bali, Borneo, Tahiti, at the Angkor Vat and of the Taj Mahal. The material which he collected

and the records which he made on these numerous trips formed a source of valuable information concerning the tropics as well as the diseases common to them, and these he used to excellent advantage in his lectures on pathology and in his seminars with students.

MacCallum never married. It may have been partly on this account that he seemed to many of those who knew him to lead, in some respects, a curiously isolated life. Not that he was a recluse, for he often sought society and had hosts of friends and acquaintances all over the world; but he was rather fastidious in his tastes; while his intellectual qualities, his acute perception and his sensitiveness appeared to require an immediate and sympathetic response, without which his interest seemed to fade away.

He showed, nevertheless, a generous feeling of responsibility and affection towards the members of his own family, and he was always loyal to his many friends, though he reserved a real devotion for a very few.

The role which MacCallum's father played in the son's life was undoubtedly an important one; for the help and inspiration which the youthful MacCallum must have received from his father was repaid in later years by the constant devotion of the son. He was ever thoughtful of his father's needs, and when the elder MacCallum retired from his active work in Canada and moved to New York to be with his son, William MacCallum equipped a room in his laboratory where his father could work to his heart's content, and where the old gentleman spent many happy years in studying the parasites of fish of which he found some new varieties.

While MacCallum was a student at Toronto University he came under the influence of Ramsay Wright, an Edinburgh man, who was a zoologist and the Professor of Biology. Wright's particular field of interest was comparative anatomy, and it has been said that MacCallum's attraction towards the biological sciences was first aroused through this association. It is, however, clear that the one person who probably had the most profound influence upon his life was Dr. Welch. The

admiration and devotion which MacCallum showed for Dr. Welch approached that which he had for his father. The attachment was formed early when MacCallum first entered upon his career in pathology and continued uninterruptedly until the time of Dr. Welch's death. It was natural that MacCallum should turn to Dr. Welch for advice concerning the problems upon which he was working in the laboratory, and it is probable that he rarely embarked upon an investigation without discussing at some time the situation with him. Certain it is that the respect for Dr. Welch's judgment, and reliance upon his counsel grew to such an extent that MacCallum rarely made any important decision on policy without seeking his advice. It would perhaps be impossible to overestimate the influence which the older man with his wisdom and knowledge and his balanced judgment exerted upon the younger man with his enthusiasm, his brilliance and his ingeniousness that sometimes appeared almost erratic. It is not surprising, therefore, that while MacCallum worked in the congenial and inspiring atmosphere of Dr. Welch's laboratory his genius for original investigation flourished.

MacCallum's contributions to pathology and to the biological sciences were numerous, varied and often highly original, and as remarked above the most productive years were those which he spent in Baltimore before he went to New York. He published a great deal during this period, but there were three major contributions of such importance as to deserve special attention.

The first of these was, in fact, a notable discovery. It was made under somewhat unusual circumstances, while he was still a student at the medical school.

His summer vacations were spent at Dunnville with his family where there was, what he described as "a makeshift laboratory in the woodshed" of his father's house, in which Dr. George MacCallum and his sons examined specimens culled from the countryside. During the summer of 1896 William MacCallum was interested in the study of the malarial parasites of birds and spent much time examining the blood of crows infected

with the "Halteridium" parasite. According to his own account, he obtained blood from a crow one day when he was far from home, so that he was obliged to bicycle several miles before he could inspect this particular specimen under the microscope. On careful examination he saw very actively motile forms of the malarial parasite which he had never observed before. It was evident that the crow itself must be had for further study and consequently he went back and procured the bird so that he might watch the parasites in the blood for long periods of time, for it occurred to him that these peculiar bodies might have developed during the long ride on his bicycle. These further observations led to the discovery of the penetration of flagellated forms of the non-granular gametocyte *(microgametocyte)*, or extracellular parasite, into the granular gametocyte *(macrogamete)*, which was then transformed into the actively motile body that had originally excited his interest.

Though the flagella of the malarial parasite had been frequently seen and described before, these structures were supposed to represent nothing more than degenerated forms of the plasmodium. This view was especially supported by the Italian investigators. MacCallum was convinced, however, that he had observed a sexual conjugation of the parasite, and concluded that the granular extracellular form was the female, the non-granular form the male, and that the flagella corresponded to spermatozoa, which entered the female parasite with consequent fertilization. He noted that never more than one of the flagella was able to penetrate the female gametocyte. On his return to Baltimore he succeeded in showing that the same process took place in the aestivo autumnal parasite of human malaria. Somewhat later Ross discovered that the fertilized motile form of the malarial parasite penetrated the wall of the mosquito's stomach where it formed spores.

The second contribution was of a totally different character. MacCallum went to Germany in 1900 where he worked in Marchand's laboratory in Leipzig. There he embarked upon a study of the lymphatics in the skin of the pig embryo. These experiments were completed and published (1903) on his return

to Baltimore. The relation of the lymphatic system to the connective tissue spaces was, at that time, not clearly defined, and there was still a question as to whether the tissue spaces opened into the lymph channels either directly, by canaliculi, or through pores or stomata in the walls of the lymphatic vessels. MacCallum was able to demonstrate that the walls of the lymphatics, although extremely delicate and easily ruptured, are nevertheless possessed of a complete endothelial lining which shows no pores or open communications with the surrounding tissue. The structure of the walls of the lymphatics, therefore, is thus analogous to the lining of blood vessels. The well known ability of solid particles to pass into the lymphatics could be explained, MacCallum thought, by the process of phagocytosis. It seemed reasonable to suppose that leucocytes might penetrate the wall of the lymph channels as readily as the wall of blood vessels and in doing so could carry with them the solid particles which they had previously engulfed. Somewhat later in an investigation of the lymphatics of the diaphragm and of the peritoneum of the dog, he was able to show that this actually occurred; for when granular material was placed in the peritoneal cavity it was readily taken up by leucocytes and carried by these phagocytes first through the lining cells of the peritoneum, and then between the endothelial cells forming the walls of the lymphatics into the actual lumina of the lymphatic channels. The structure of the lymphatics in the diaphragm, however, was such, and the mechanical action of the diaphragm during respiration upon them so contrived that a few solid particles were forced or sucked into the lymphatic lacunae and lymph channels without the intervention of phagocytes.

MacCallum devoted a great deal of time, throughout his career to a study of the glands of internal secretion. This interest developed very early, for even in 1903 he was investigating the structure of the thyroid and parathyroid glands. At that time his investigations were directed towards the supposed interrelation between the function of the thyroid gland and parathyroid bodies, about which there was some confusion and uncertainty. Experiments made a little later convinced him

that the function of the thyroid and parathyroids is entirely independent, a conclusion which was in accord with results obtained by some previous investigators. It became clear, therefore, that tetany which had long been known as an occasional sequel to operations upon the thyroid gland was due entirely to injury or removal of the parathyroid glands. Some previous reports had been published, by Vassale and others, which appeared to show that tetany, following the experimental removal of the parathyroid glands, might be modified or favorably affected by injections of emulsions of the parathyroid material, and MacCallum found that the intravenous injections of emulsions of the parathyroid glands of dogs and of beef would sometimes control the symptoms in experimental tetany of dogs, though this could only be accomplished with some difficulty. The probability had occurred to MacCallum that some metabolic disturbance followed the removal of the parathyroid glands, which could account for the acute symptoms of tetany, and that the disturbances might be reflected in an abnormality of the blood. Several physiologists, among whom was Jacques Loeb, had called attention to the fact that the loss of calcium from the body would result in muscular twitchings, or, as Sabbatani had shown, to an increased excitability of nerve cells. With the assistance of the chemist, Carl Voegtlin, therefore, MacCallum made studies upon the effect of the injection of salts of calcium, sodium, magnesium and potassium in experimental tetany. The results of these important experiments were published in 1905. The conclusions were that the injection of a solution of a calcium salt into the circulation of an animal in tetany checked all the symptoms and restored the animal to an apparently normal condition; whereas the intravenous injections of sodium and potassium salts had no such beneficial effect. The injections of magnesium salts were toxic in themselves. It was also found that there was a marked reduction in the calcium content of the tissues, especially of the blood and brain, during tetany and at the same time an increased output of calcium in the urine and faeces. These experiments, which have now become classical, went far to

elucidate several perplexing problems relating to the mechanism of tetany. They demonstrated that the parathyroid secretion in some way controls the calcium exchange in the body, and in the absence of the parathyroid glands, an impoverishment of the tissues with respect to calcium takes place with the consequent development of hyperexcitability of the nerve cells and tetany. Only the restoration of calcium to the tissues can prevent this. Further experiments upon the galvanic hyperexcitability of the nerves, which was found to be a characteristic feature of tetany, were reported to the German Pathological Society in 1912. By severing nerve trunks and through transfusion of the limbs of dogs it could be shown that the hyperexcitability was due to some change in the blood which followed removal of the parathyroid glands, and which was capable of affecting the nerve terminals.

It had long been known that an entirely different form of tetany, described as gastric tetany, occurs not infrequently in children and in adults who suffer from an obstruction at the pyloric outlet of the stomach. In this form of tetany the parathyroid glands are normal. MacCallum was naturally attracted to a study of this condition, and in 1909 started some observations on dogs in which the pylorus had been closed by an operative procedure. The experiments were continued in New York and a preliminary report of the results was made before the American Society for Experimental Pathology in 1917, but owing to the press of work during the war and his departure for Baltimore the final paper was not published until 1920. These studies demonstrated that when the pylorus was obstructed and the gastric juice with its hydrochloric acid was removed, there ensued a decrease in the chlorine of the blood plasma. Accompanying this loss of chlorine there was an increase in the alkali reserve of the blood which became extreme. The electrical excitability of the nerves was in general heightened and spontaneous twitching of the muscles appeared. In most of the dogs violent convulsions led to death. All of this could be prevented if chlorides were constantly furnished to the animal. These experiments led to the conclusion that the

mechanism responsible for gastric tetany was totally different from that following parathyroidectomy, for in gastric tetany the electrical excitability of the peripheral nerves was dependent upon an imbalance of the electrolytes of the blood, due to the constant and excessive loss of hydrochloric acid.

His interest in the thyroid gland led also to careful studies of the pathological changes in this organ removed from patients with exophthalmic goitre, and to observations on the mechanism of the remarkable exophthalmos that is such a striking and characteristic feature of Graves disease.

The physiology of the circulation in valvular disease of the heart attracted his attention at one time, and he devised methods to study the problem experimentally. Long hooks and ingeniously contrived knives were made with which he could cut or injure the valves of the heart in the anaesthetized dog without opening the heart itself. This was accomplished by passing the instruments through the carotid artery into the chambers of the heart. With this technique it was possible to produce most of the lesions of the heart valves that are commonly encountered under pathological conditions in man. Both insufficiency and stenosis of the mitral valve were successfully initiated, while regurgitation of the aortic valve was quite readily reproduced. The principal value of these experiments was that they furnished an opportunity to study the direct effect which these lesions had upon the mechanics of the circulation; but another use to which they were put with excellent effect was to teach medical students pathological physiology. The novelty of these experiments, the ingenuity with which they were carried out, and their application to the teaching of pathological physiology attracted considerable attention.

In 1917 and 1918 an opportunity came to study the pathology of epidemic pneumonia which was sweeping through the army camps in this country and causing great numbers of deaths. The situation was complicated first by the epidemic of measles and then by the pandemic of influenza. MacCallum's important and extensive studies were published in several papers and

finally collected in a monograph which stands as one of the most comprehensive studies upon the subject.

MacCallum was always devoted to the study of pathological anatomy and throughout his life published innumerable descriptions of unusual forms of disease or of peculiar lesions occurring in common diseases that had escaped the attention of others. As he grew older he tended to confine his attention to this form of investigation, and added considerable information, gained from a meticulous microscopical study of tissues, to the existing knowledge of the finer structure of many pathological lesions.

His eminence in this field was unquestioned. He was invited to give many important lectures, among which were the Harvey Lecture, the Beaumont Lecture, and the Harrington Lectures. In 1940 he was appointed by the Association of American Physicians to be Kober Lecturer.

He was an active member of many scientific societies in this country, an Honorary Fellow of the Royal Society of Medicine, corresponding member of Societas Regia Medicorum Budapestinesis, an Honorary Member of the Societé d' Endocrinologie of Paris and an Honorary Member of the Pathological Society of Great Britain and Ireland. He was elected a member of the National Academy of Sciences in 1921.

In the winter of 1943 he suffered an illness which forced him to go to Florida for a rest. Shortly after his arrival he was stricken with a hemiplegia which steadily progressed until he was completely incapacitated. His death occurred on February 3, 1944.

MacCallum was undoubtedly one of the outstanding pathologists in this country and was, moreover, recognized internationally for his original investigations. His attainments might be attributed in large part to a peculiar combination of respect for tradition and search for the unknown.

On the one hand, he upheld vigorously the opinion that a knowledge of pathological anatomy was of fundamental importance for a proper understanding of clinical medicine. True to the conventional training of older pathologists, he never

relinquished his habit of acute observation of morbid states, and in consequence enriched the descriptive science by constantly adding new information.

On the other hand, he was forever stressing the vast unknown, pointing out the flaws in arguments and finding the weak links in a chain of evidence that led to unconvincing conclusions. In his experimental work he discarded all previously conceived ideas, and by using any methods that were available or that might be adapted to his purpose attacked the problem from a new and original point of view. Though MacCallum's important experimental investigations were not great in numbers they were original in conception, and so complete and accurate in their conclusion that some should remain as permanent contributions to medical science.

KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

Am. Jour. Dermat. and Genito-Urinary Dis. = American Journal of Dermatology and Genito-Urinary Diseases
Am. Jour. Hygiene = American Journal of Hygiene
Am. Jour. Med. Sci. = American Journal of Medical Sciences
Am. Med. = American Medicine
Anat. Anz. = Anatomischer Anzeiger
Arch. f. Anat. u. Entwck. = Archiv für Anatomie und Entwickelungsgeschichte
Arch. Path. = Archives of Pathology
Beit. zur path. Anat. u.z. Allg. Path. = Beitraege zur Pathologischen Anatomie und zur Allgemeinen Pathologie
Brit. Med. Jour. = British Medical Journal
Bull. Amer. Mus. Nat. Hist. = Bulletin, American Museum of Natural History
Bull. Hist. Med. = Bulletin of the History of Medicine
Centralbl. f. d. Grenz. d. Med. u. Chir. = Zentralblatt für die Genzgebiete der Medizin und Chirurgie.
Centralbl. f. allg. Path. u. path. Anat. = Zentralblatt für Allgemeine Pathologie und Pathologische Anatomie
Centralbl. f. Bakteriol. u. Parasitenk. = Zentralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten
Ergebn. d. inn. Med. u. Kinderh. = Ergebnisse der Inneren medizin und Kinderheilkunde
Gaillard's Med. Jour. = Gaillard's Medical Journal
Int. Assoc. Med. Mus. = International Association of Medical Museums
Int. Clin. = International Clinics
J. H. H. Bull. = Johns Hopkins Hospital Bulletin
J. H. H. Repts. = Johns Hopkins Hospital Reports
Jour. Am. Med. Assoc. = Journal, American Medical Association
Jour. Exper. Med. = Journal of Experimental Medicine
Jour. Mt. Sinai Hosp. = Journal of Mt. Sinai Hospital
Jour. Morph. = Journal of Morphology
Jour. Path. and Bact. = Journal of Pathology and Bacteriology
Jour. Pharma. and Exper. Therap. = Journal of Pharmacology and Experimental Therapeutics
Louisville Mo. Jour. Med. and Surg. = Louisville Monthly Journal of Medicine and Surgery
Med. = Medicine
Med. Clin. N. Am. = Medical Clinics of North America
Med. News = Medical News
Med. Rec. = Medical Record
Mitteil. a. d. Grenzg. d. Med. u. Chir. = Mitteilungen aus den Grenzgebeiten der Medizin und Chirurgie

Physiol. Rev. = Physiological Reviews
Proc. N. Y. Path. Soc. = Proceedings, New York Pathological Society
Proc. Path. Soc. Phila. = Proceedings, Pathological Society of Philadelphia
Proc. Soc. Exper. Biol. and Med. = Proceedings, Society for Experimental Biology and Medicine
South. Med. Jour. = Southern Medical Journal
Tr. Assoc. Am. Phys. = Transactions, Association of American Physicians
Tr. South. Surg. Assoc. = Transactions, Southern Surgical Association
Verh. d. Dtschn. Path. Gesellsch. = Verhandlungen der Deutsche Pathologische Gesellschaft
Zool. Jahrb. Abth. f. Systematik = Zoologischen Jahrbücher Abtheilung für Systematik

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OF

STEPHEN WALTER RANSON

1880–1942

BY

FLORENCE R. SABIN

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1944

STEPHEN WALTER RANSON

1880–1942

BY FLORENCE R. SABIN

Stephen Walter Ranson, Professor of Neurology and Director of the Institute of Neurology at Northwestern University, died of coronary thrombosis on August 30, 1942. He was born August 28, 1880, at Dodge Center, Minnesota. He was the son of Stephen William and Mary Elizabeth (Foster) Ranson who were of English and Welsh descent. It is clear that he came of a medical family, for his father was a physician and of the six children, three became physicians and one received a Doctorate of Philosophy in Psychology.

Ranson was graduated from the University of Minnesota in 1902. He then went to Chicago University, where he took the Master's degree in 1903 and the Ph.D. under H. H. Donaldson in 1905. He was a Fellow in Neurology at Chicago from 1904 to 1906 and received his medical degree at the Rush Medical College in 1907. After a year of interneship at the Cook County Hospital, he became Associate in Anatomy at the Northwestern University Medical School through the influence of Prof. Arthur W. Meyer. From then on there was no break in his successful academic career. In 1910-11 he studied under Wiedersheim in Freiburg; in 1912 he became Professor of Anatomy at Northwestern University. In 1924 he went to Washington University School of Medicine in St. Louis as Professor of Neuroanatomy and Head of the Department of Neuroanatomy and Histology. In 1926 he spent the summer at Queen's Square Hospital, working with Gordon Holmes and Kinnier Wilson in the clinics. He remained at Washington University only four years and in 1928 was induced to return to Northwestern University Medical School as Professor of Neurology and, more important still, as Director of a new Neurological Institute to be organized in recognition of the value of his research.

Ranson was the combination of teacher-investigator. He trained many students in research as is evident from his bibliog-

raphy, and an exceptional number of his students are now heads of departments in our medical schools. Through his textbook on the Anatomy of the Nervous System he has influenced medical students in practically all of our schools. It is, however, interesting to note that in spite of the marked swing toward physiological interests in his research, this interest was reflected best in the last or seventh edition of his book.

Ranson received many honors. He delivered the Weir Mitchell Oration in 1934, a Harvey Lecture in 1936, the Dunham Lectures in 1940, and the Hughlings Jackson Lecture in 1941. He was a Fellow of the American Association for the Advancement of Science, a Member of the National Academy of Sciences, the American Neurological Association, the American Physiological Society, and the American Association of Anatomists, of which he was president from 1938 to 1940.

In 1909 Ranson married Miss Tessie Grier Rowland of Oak Park, Illinois, who made their home a center of hospitality. There were three children—one son and two daughters. His son, now Captain Stephen Ranson, became a physician, and it must have been a great gratification to him that in 1941 both his son and one daughter, Mary Ranson, collaborated with him in research.

Medical research in this century is characterized by a breaking down of the barriers between different disciplines, barriers which grew up in the last century because the problems then attacked needed the development of highly specialized techniques. In the present phase new types of problems have come to the fore, which need not one but a wide range of these techniques. Nowhere is this new type of research more happily illustrated than in neurology when, at the turn of the century, Sherrington (summarized in 1906 by the publication of his book, "The Integrative Action of the Nervous System") unraveled the mechanism of "how the animal stands," and thus wiped out all artificial barriers between anatomy and physiology.

Ranson began his work at the start of this new era and developed with it. His training had been strictly anatomical. He first discovered that there are more unmyelinated than myeli-

nated fibres in the dorsal roots, and then proved that these unmyelinated fibres were afferent in function and followed their central connections. He studied their relation to the sympathetic system and finally became the acknowledged leader in the field of the physiology of the hypothalamus, the center of control for the sympathetic system and for water balance.

Ranson's first work concerned the question of whether there is retrograde degeneration, as well as direct, and he proved it in the affirmative by the use of the double pathway of the corpus callosum (1, 2).* His next study, published in 1906 and constituting the dissertation for his Ph.D. degree (4), was entitled "Retrograde degeneraton in the spinal nerves," but the subject matter was more significant than the title. The procedure suggested to him by Donaldson was to cut a spinal nerve, allow degeneration and then count both the myelinated axons in the corresponding roots and the cells in the spinal ganglion. Since 1896 (Gaule and Lewin) it had been known that there are more cells in a spinal ganglion than there are myelinated fibres in its root. The studies of Gaule and Lewin, with those of Hatai [1902] and of Ranson, showed from three to six cells per fibre, varying both from nerve to nerve in the same animal and from animal to animal (138). Ranson went on to find the meaning of this fact, namely, that 70 per cent of the cells, known to be smaller than the rest, give rise to unmyelinated fibres. The existence of unmyelinated fibres in spinal ganglia was just becoming known, for example, to Cajal [1906] and to Dogiel [1908], but it was Ranson's contribution to demonstrate how large their number, even more than myelinated fibres, and to work out their peripheral distribution and their central connections. Thus he extended our knowledge, of this afferent system (5-7, 8-13) and, indeed, it was these studies, carried on over a long term of years and showing remarkably sustained interest, that laid the foundation of Ranson's career in neurology.

The conventional way of staining nerves with osmic acid had stressed only the myelin sheaths; but, with the introduction of

* Figures in parentheses refer to the numbers of titles in the accompanying bibliography.

silver methods, axons were brought out. Ranson modified one of Cajal's silver methods, making the so-called pyridine silver technique (7, 10) which permitted the discrimination of axons from connective tissue fibres and from neuroglia. The axons of myelinated fibres stained yellow in the center of clear, unstained rings of myelin, while the axons of the unmyelinated fibres were brown or almost black.

In the study of spinal ganglia (10,13) with the pyridine silver method, Ranson found, as had Dogiel, more variations in the type of origin of the single axon, single, branched, or plexiform, from both large and small cells, than can be related to functional differences, but the common and essential characteristic of all of them was the bipolar division into two branches. Of the unmyelinated fibres the branch which entered the cord was smaller than the one which ran into the peripheral nerves. He found that the spinal nerves carried more unmyelinated fibres than myelinated ones, and far more fibres than could be accounted for by the postganglionic, motor, sympathetic fibres. In the peripheral nerves most of the afferent, unmyelinated fibres were distributed to the cutaneous nerves and only a few to the muscular branches (104,124).

Ranson surveyed these unmyelinated fibres from the ganglia of the trigeminus and the vagus complex (19, 23, 25). In the sensory ganglia of the vagus he found the same predominance of small, unipolar cells giving rise to afferent, unmyelinated fibres. He then was able to complete the study of the two kinds of roots of the vagus begun by the Belgian anatomists, Van Gehuchten and Molhant, first, the efferent roots containing two sizes of myelinated fibres, many small and a few large ones, and second, the more varied afferent roots, containing many more unmyelinated than myelinated fibres, the latter being of all sizes —large, medium, and small (12, 13, 19).

The number and distribution of this extensive, afferent, unmyelinated system could be established only in animals in which the sympathetic chain had been removed (102). This he did both opposite the lumbar plexus and in other animals opposite the brachial plexus. After allowing time for complete degenera-

tion of postganglionic fibres, he made comparative studies of a nerve to the skin and one to muscle. In a cutaneous nerve he found 3.5 residual unmyelinated fibres, hence afferent in type, for each myelinated one. For the vagus complex (125), he found the persistence of the afferent, unmyelinated fibres after elimination of the sympathetic fibres induced by removing the superior cervical ganglion and after cutting the vagus roots as well.

This concept that there are unmyelinated fibres which are sensory in type made necessary a restudy of the sympathetic system (34, 36, 39, 43, 101, 102, 124). Ranson found that all the sensory cells for the viscera were in spinal ganglia or their cranial counterparts. Their fibres were both unmyelinated and myelinated. As Langley had found, Ranson confirmed that when a spinal nerve was cut distal to a spinal ganglion, nearly all the fibres of the corresponding white ramus degenerated, which would not have happened if afferent fibres were running from the sympathetic chain to spinal ganglia (43). When the efferent sympathetic fibres were removed from a white ramus by cutting the nerve roots proximal to the spinal ganglion (39), the visceral afferent fibres remained in the white rami; they are myelinated fibres of all sizes, as well as unmyelinated, and they run not diffusely but in compact bundles.

Structurally, the finding that all afferent cells are in spinal and the corresponding cranial ganglia means that the sympathetic ganglia are entirely efferent in type. Ranson therefore restudied these ganglia. As was well known, the cells are multipolar with exceedingly complex dendrites and with an axon that becomes a postganglionic, efferent fibre, for the most part unmyelinated.

The axons of the preganglionic fibres, on entering a sympathetic ganglion, such as the superior cervical ganglion, form an extensive plexus of branching axons in the intercapsular spaces of the ganglion. They come into synaptic relations with the complex, branching dendrites of the multipolar ganglion cells. In the human being, besides the extracapsular dendrites of the sympathetic ganglia, there are also complex intracapsular dendrites, making large glomeruli of processes often from several

cells. Ranson found that when all the preganglionic fibres entering the superior cervical ganglion had been cut, with resulting degeneration of their axons, there was no evidence for association neurons either within one sympathetic ganglion or between two or more of them (34, 36, 39, 40, 41, 42, 43). It is probable that each preganglionic fibre ends on several sympathetic cells. Huber has pictured one entering axon in relation to seven cells, and Ranson found thirty-two sympathetic ganglion cells to each entering axon (42).

Ranson thus came to the generalization that all the cells of the spinal ganglia are unipolar, with T or Y shaped processes, that is to say, they are afferent in type. This conclusion was reached only after ruling out two puzzling structures, first, the so-called pericellular baskets described by Dogiel in 1908, which might be synapses, motor in type, in spinal ganglia, and second, possibly multipolar cells in these ganglia described by Kiss. Ranson (127) showed that the Kiss cells were artefacts due to shrinkage. For a long time Ranson (58, 59, 60, 63) believed that Dogiel's pericellular baskets might be synapses, motor in type, within spinal ganglia, but he finally saw that the strongest evidence for their existence, the apparent blocking of impulses by painting nicotine on spinal ganglia, was faulty (60). Moreover, it was finally shown that these pericellular networks are probably a reaction to injury (see: Barris, a pupil of Ranson, *J. Comp. Neurol.*, 1934, *59*, 325; also p. 53 in Ref. 213).

Thus it finally becomes clear that Ranson established the fact that a large proportion of afferent fibres are unmyelinated in type, that they arise from the small cells of spinal ganglia and the corresponding cranial ganglia and that these ganglia contain only afferent fibres.

Ranson then proposed to study the pathways of the unmyelinated system in the spinal cord. In this work he combined with a pharmacologist, von Hess (27), and a surgeon, Billingsley (29-33). On studying the entry zone of the dorsal roots, they found that all of the unmyelinated fibres were segregated into the lateral border of the roots and entered Lissauer's tract bordering the substantia gelatinosa of Rolando which made a nucleus

of reception for them (14-17, 20, 21, 26). Moreover, an important structural point became clear, namely, that all entering unmyelinated fibres are short, ending (29) almost completely in their segment of entry with perhaps slight overlapping into the next above. In this characteristic they agreed with the known paths of pain and temperature. As a matter of fact, the concept that the unmyelinated fibres might carry pain and temperature impulses was suggested to Ranson (20) by a parallelism between these two types of sensory fibres, and Head's concept of two types of functional sensory paths, protopathic or epicritic. At that time Head's work had not been refuted. The separation of unmyelinated fibres in the cord is not complete for a few fine, myelinated fibres also enter Lissauer's tract, but the vast majority of myelinated fibres, as had long been known, become the posterior ascending columns. Lissauer's tract as the zone of entry of the unmyelinated fibres proved characteristic of all the animals commonly used in experimental work (15, 20). Also, Lissauer's tract itself contains no long neurons (31), none extending more than two or three segments, and thus (29) represents intersegmental conduction paths.

It was found possible in the lower segments, where the dorsal root bundles are longer, to cut the lateral, unmyelinated bundle and the medial, myelinated one separately (27, 29-33, reviewed in 47). Also Lissauer's tract, and of course the posterior columns, could be eliminated separately. When the medial (myelinated) roots or the posterior columns only were cut, there was no loss in pain and no change in vasomotor reflexes (27, 98). On the other hand, stimulation of the lateral, unmyelinated root fibres, studied in the 7L and 1S segments, gave rise to struggling and to a reflex rise in blood pressure (38, 98). Hence Ranson concluded that the unmyelinated fibres carried pain impulses. These studies, Ranson (98) considered as his best evidence that unmyelinated fibres mediate pain. More conclusive evidence was finally provided by Gasser and Erlanger (*Amer. J. Physiol.*, 1929, *88*, 581) who showed, by means of the cathode ray oscillograph, that some of the fibres that carry pain may be the smallest in the nerve.

It had long been known that the stimulation of the central end of a nerve might give rise to either a fall or a rise in blood pressure. In 1895, Hunt had shown that depressor responses were elicited by weak stimuli, that is to say, had a low threshold, while pressor impulses had a high threshold. In following the pathways for pain and temperature in the cord, Ranson and Billingsley found that destroying Lissauer's tracts and the posterior horns of both sides abolished the pressor reflex but not the depressor. Under these conditions, continued stimuli merely increased the fall in pressure. The pressor pathway ran on both sides but predominantly homolaterally. The destruction of Lissauer's tract did not abolish consciousness of pain but only that part of the pain and temperature mechanism associated with the pressor reflex functionally, and structurally only that part which is intersegmental within the cord. The pressor reflex path for the vessels of the head was found to be in the tractus spinalis N. V., as was shown by cutting the tract, an experiment carried out by Miss M. Wilson, a pupil of Ranson, in 1921.

The pathway for the depressor reflex, demonstrated by stimulating the sciatics with a weak current, was abolished only by cutting both lateral columns, and proved to be predominantly crossed. This pathway has fewer and longer neurons (27, 32, 47) than the pressor path. When the depressor reflex has been eliminated by cutting both lateral columns, a moderate current excites a pressor effect (32), suggesting that, in the intact cord, there is an algebraic summation of pressor and depressor impulses. The structural differences between the pressor and depressor pathways, the former of many short neurons, Lissauer's tract, and the latter of a few long ones in the lateral columns, Ranson thought might account for their marked difference in threshold. But it is now known that differences in the rate of conduction of impulses, as shown by Dr. Gasser and his associates, also enter as a factor.

Ranson and Billingsley (33) were aware that these pathways were not simple, for they found that lesions of the posterior gray matter low in the cord cut off pressor effects induced by

strong stimuli of the sciatic nerves, but that if lesions were made higher up, there was less disturbance, suggesting alternate pathways probably in the gray matter of the cord. It was clear that the main arc for pressor impulses was not complete in the cord. They then exposed the floor of the fourth ventricle (30) and found a pressor point at the apex of the ala cinerea and a depressor point in the area postrema just lateral to the obex.

The peripheral mechanism for vasodilators proved complex and difficult to analyze, both from the obscurity in postulating the mechanism, that is, how a vessel can be made to dilate actively, and from the nature of the nerve impulses associated with the process. As early as 1876, Stricker had postulated dilator fibres, and in 1901 and 1908, Bayliss had proved their existence and shown that for the hindlimbs the cells of origin were in the lower lumbar and first sacral spinal ganglia. He postulated antidromic conduction along nerves afferent in type. Ranson [1922] now proposed to explore the relation of the unmyelinated fibres to this concept. After postulating (49) and finally discarding the idea that there are synapses in the spinal ganglia, Ranson and his associates (50, 51, 53) devised an experiment in which they could separate peripheral and central effects on vasodilators. They placed a dog's leg in a plethysmograph, cut and tied the opposite iliac artery, and pulled it out through an opening in the flank, so that thus they could inject through it directly past the bifurcation of the aorta into the vessels of the opposite leg. Then, in the completely denervated leg, they obtained vasodilation with nicotine. These experiments, they concluded, confirmed the work of Dale and Richards (*J. Physiol.*, 1918, *52*, 110) by which these investigators had shown that vasodilation is a function of the arteries and capillaries themselves, not initiated by nerve impulses but subject to regulation by them. Thus the mechanism for vasodilation proves to be different from that for constriction of the vessels, the latter being mediated directly through sympathetic ganglia, the former being primarily a peripheral mechanism.

These studies on vasomotor pathways made Ranson formulate the concept that the unmyelinated fibres which form the afferent

part of their arcs carry pain and temperature impulses. Since these fibres were the smallest in the nerve, he analyzed a given cutaneous nerve in terms of size of fibre, as well as in the proportion of myelinated and unmyelinated fibres, and compared the data with the known punctate sensibility of the area of skin supplied by this nerve. At first in a study of the median cutaneous nerve of the forearm (123), he found a remarkable statistical parallelism with the studies of von Frey; for example, he found 90 per cent small fibres to be compared with 87 per cent pain points; but with other nerves, such as those for the scalp (138), he found that the correlation broke down completely because there were many more fine fibres, both myelinated and unmyelinated, than there are pain spots and far too few large fibres for the touch spots. Thus, Ranson saw from his own work that size of fibre does not correlate with function, which had been more conclusively proved by direct rather than by indirect evidence by Dr. Gasser (*Research Publications,* Assoc. Nervous and Ment. Dis., 1935, *15,* 35) who showed that rate of conduction and diameter of fibre do correlate with each other, but neither corresponds to function.

It is thus clear that Ranson had established his discovery of an extensive system of unmyelinated afferent fibres, had worked out their peripheral distribution, had demonstrated that their entry zone into the cord is Lissauer's tract and its medullary extension, the tractus spinalis N. V, and had proved that this tract is a part of the mechanism for vasomotor pressor reflexes and that hence these unmyelinated fibres are a part of the mechanism for the conduction of pain and temperature impulses. But it is also clear that the fine, unmyelinated fibres, C types in physiological terms (Gasser, H. S., *J. Neuro-Physiol.,* 1939, *2,* 361), are not the exclusive pathways of pain, since Dr. Gasser (*Research Publications,* Assoc. Nervous and Ment. Dis., 1935, *15,* 35) showed that pain is carried by larger fibres of the B type which are myelinated, and Dr. Tower (Tower, S. S., *Proc. Soc. Exp. Biol. and Med.,* 1934-35, *32,* 590) demonstrated that sensory fibres from the cornea conveying pain are mainly

myelinated (*J. Neuro-Physiol.*, 1940, *3*, 486), the slowly reacting C fibres not being demonstrable.

For a period of years Ranson became interested in the subject of postural contraction or muscle tonus, in part through the stimulus of Sherrington's studies on decerebrate rigidity and in part through his own interest in making as complete a survey as possible of the functional rôle of the spinal ganglia. In the study of decerebrate rigidity, it appeared that there was a perfect example of tonus, involving a type of contraction with marked lack of fatigue and lack of heat production. Moreover, Sherrington had noted that the muscle had also a certain degree of plasticity. There developed then a concept of three different types of activity in muscle, the usual phasic contraction, contractile tonus, and plastic tonus.

Sherrington and Brown had shown that the dorsal roots are necessary for tone—in Sherrington's view through propioceptive impulses. Ranson, defining tonus (69) as "the steady, indefatigable contraction required for posture," felt that Sherrington's concept did not account adequately (64) for the lack of fatigue. He proposed to explore two mechanisms as possibly related to the phenomenon, (a), the question of sympathetic connections, and (b) the question of action through the spinal ganglia either by motor impulses or by antidromic conducton along afferent fibres. The subject proved baffling and Ranson's own studies did not unravel the nature of the mechanism nor why it is not subject to measurable fatigue. This phenomenon has since been explained by the nature and timing of certain impulses through motor nerves.

Hinsey and Ranson (66) found that after complete removal of the left lumbar sympathetic chain, followed after 50 to 75 days by decerebration, there was no difference in tonus on the two sides, as indicated by posture, by measuring resistance to flexion and by the effect of tetanus toxin. This ruling out of the sympathetic system from the mechanism of tonus confirmed the work of van Rijnberk [1917], and is in complete agreement with the studies of Cannon. As has been stated, Ranson became convinced that there are no motor synapses in the spinal

ganglia. Moreover, the absence of any endings of dorsal root fibres in striated muscle, as demonstrated by Hinsey (78), ruled out direct efferent impulses through the spinal ganglia and any mechanism for making antidromic impulses effective on muscle fibres (78), but did not analyze the rôle of afferent impulses in tonus. During these studies, Ranson (101) found that it was practically impossible to de-afferent the hind legs in cats without a certain amount of damage to the cord because the operation could not be done without opening the dura. In this case cutting of the afferent nerves was followed by an immediate loss of tone with subsequent extensor rigidity. For the forelimbs, on the other hand, it was not necessary to open the dura in order to cut the dorsal roots, in which case Ranson found that the immediate loss of tonus was not followed by an overaction of the extensors. This gave to Ranson (101) the evidence that afferent impulses do not play an exclusive rôle in maintaining tonus.

Concerning the central relations of the mechanism for tonus, Ranson and Hinsey (79, 80) made an important advance. Sherrington had shown that in decerebrate rigidity, when the afferent nerves were intact, the crossed extensor reflex was expressed as a slow contraction followed by a prolonged, slow decline, but that when the limb was de-afferented, both contraction and relaxation were rapid. Ranson and Hinsey (80, 81), using the so-called anemic method of decerebration of Pollock and Davis (tying both carotids and the basilar artery), got, on the other hand, a quick response and a slow relaxation. They therefore made transections at different levels of the brain-stem and found that maximum rigidity occurs when the mesencephalon is thrown out (80) and that a cut across the upper border of the mesencephalon, leaving most of the red nucleus intact, gave a quick contraction and quick relaxation; while a cut between midbrain and pons, eliminating the effect of the rostral midbrain, gave the slow reaction of the Sherrington type. They concluded that the rate of response is not due entirely to peripheral, afferent impulses but rather is under central control as well; that in the upper end of the midbrain is a center for regulating tone.

When the transection is low down, the inhibition of this center has been cut off, and the tonic response and relaxation are both slow. Thus they conclude that there is a center in the neighborhood of the red nucleus for tonus, inhibitory in action, that is, mediating cerebral impulses, but that this is not the only center for tonus, since tonus is still present when the hypothalamus is intact as well as the cerebellum. They consider that decerebrate rigidity with intact red nuclei is due in part to the removal of inhibitory influences from the cerebral cortex.

Ranson now began the most important work of his career, the study of the correlation of structure with function in the hypothalamus. He had now [1928] become Director of an Institute of Neurology where, with a large group of associates, his entire energies could be devoted to research.

The experimental approach to the hypothalamus had been initiated in 1909 and 1910 by Karplus and Kreidl who reported excitation of the sympathetic system from stimulation of the hypothalamus. Professor Cannon, in a long series of studies, had shown that the entire sympathetic system acts as an integrated mechanism for the expression of fear and rage. The reactions consist of constriction of the blood vessels, chiefly those supplying the abdominal viscera, producing a rise in blood pressure and causing the blood to flow more rapidly through the brain, heart, and skeletal muscles. At the same time there is poured into the blood an increased amount of adrenalin which reduces muscle fatigue, and the amount of sugar is increased to supply the muscles with an abundant source of energy. There is also a dilation of the pupils and an increased rate and depth of respiration. All of these phenomena are associated with the expression of intense emotional excitement. Other functions are repressed, such as a decrease in secretory activity of the stomach and an abolition of peristaltic movements of stomach and intestine. All of these make an integrated mechanism for the expression of fear and rage. In 1928 and 1929 Bard (*Amer. J. Physiol.*, 1928, *84*, 490; *Arch. Neurol. and Psychiat.*, 1929, *22*, 230) showed that "sham rage" associated with an explosive involvement of the entire sympathetic mechanism had its coordi-

nating center in the hypothalamus. In the same year [1928], Hinsey (Ref. 77; see also page 254 in Ref. 159), working with Ranson, observed that one of the cats with decerebrate rigidity in which crossed extensor reflexes were being studied, when left without any restraint, was restless and finally succeeded in getting to its feet and walking, once even a distance of 15 feet. Moreover, in this cat there were alternate periods of quiescence and restlessness. In the experiments of Bard the animal had been restrained. Hinsey and Ranson found (77, 92) that in this animal the cut had not been strictly transverse in the line between midbrain and diencephalon, but that starting at the posterior commissure, the cut had run obliquely forward to the optic chiasm. Thus was preserved the small wedge of tissue which is the hypothalamus. In this case the entire red nucleus, the medial and lateral hypothalamic nuclei and Luys' body were intact. They had therefore found that the hypothalamus is necessary for the maintenance of the upright position and for the rhythmic movements of walking. Subsequently (in 1930, Ref. 92), Hinsey, Ranson, and McNattin found that indeed only a small part of the hypothalamus need be retained to enable a cat to walk. The cut from the rostral border of the superior colliculus (posterior commissure) dorsally need only pass in front of the mammillary bodies ventrally to retain this function. This small wedge covers the extension of the tegmentum of the midbrain, including the red nucleus, into the hypothalamus. They were aware that the meaning of the hypothalamus for this function could not be solved without determining all its relations to other parts of the mechanism of standing, such as the vestibular apparatus and the cerebellum which this small wedge of tissue might keep intact. In subsequent experiments it was found that destroying both red nuclei in the cat did not eliminate the ability to walk (120, 121, 122).

These observations on the hypothalamus as some part of the mechanism for walking were the starting point of the prolonged study of the hypothalamus made by Ranson and his associates. Their method consisted of a survey of the hypothalamus with the Horsley-Clarke stereotaxic apparatus for placing lesions

and inducing stimulations at exact, reproducible areas in the brain. This instrument was described in 1908 by Horsley and Clarke (*Brain,* 1908, *31,* 45). The following year [1909], it was used by Sachs (*Brain,* 1909, *32,* 95) in a study of the thalamus made in Horsley's laboratory. It was brought from England by Dr. Sachs to the laboratory at Washington University in St. Louis, where, many years later [1924-28], Ranson became familiar with its use. Indeed, Ranson and his associates have made most extensive surveys of midbrain, hypothalamus, and other structures of the forebrain with this instrument. Ranson (131) first made a series of charts with orientation planes for both cats' and monkeys' brains and then a series of studies on the pathways for eye reflexes was undertaken. At the time of his death Ranson and his associates were starting to survey the structures of the basal ganglia and tracts of the forebrain, but their most complete surveys were of the hypothalamus.

Ranson finally summarized the modern work on the hypothalamus as follows: The hypothalamus, which is phylogenetically a very ancient part of the diencephalon, exerts its control over a wide series of visceral functions (131, 132, 214). Two different mechanisms are involved, first, fibre connections with brain and cord by which impulses are relayed to the sympathetic system, giving the physical signs of fear and rage. In this division there is some overflow into the somatic system. The hypothalamus also acts as a thermostat for the regulation of body temperature. Second, there is a tract of unmyelinated fibres from hypothalamus to hypophysis, whose impulses control water balance. Both mechanisms act through glands of internal secretion, the first through the adrenal, the second through the posterior lobe of the hypophysis.

In the explorations of the hypothalamus all lesions and all stimulations were made bilaterally. Ranson and his associates found that the most sensitive zone for excitation of the sympathetic system was the lateral hypothalamic zone in the region of the medial forebrain bundle lying between the internal capsule and the fornix. This zone is the middle region of the hypothala-

found the areas that make a thermostat for regulating body temperature, they located the center that has to do with the waking-sleeping rhythm, and analyzed the relation of hypothalamus to hypophysis in the control of water balance.

In 1940 the volume on the Hypothalamus of the Research Publications of the Association for Research in Nervous and Mental Disease was dedicated to Ranson with the following inscription:

In recognition of the distinguished contributions

To knowledge of hypothalamic functions

Made by himself and

By the students he has inspired,

This meeting of the association

Is dedicated by the trustees to

STEPHEN WALTER RANSON

KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

Am. Heart J. = American Heart Journal
Am. J. Anat. = American Journal of Anatomy
Am. J. Med. Sci. = American Journal of Medical Sciences
Am. J. Obst. and Gynec. = American Journal of Obstetrics and Gynecology
Am. J. Ophthal. = American Journal of Ophthalmology
Am. J. Physiol. = American Journal of Physiology
Am. J. Rel. Psychol. and Ed. = American Journal of Religious Psychology and Education
Anat. Anz. = Anatomischer Anzeiger
Anat. Rec. = Anatomical Record
Ann. Int. Med. = Annals of Internal Medicine
Arch. Int. Med. = Archives of Internal Medicine
Arch. Neurol. and Psychiat. = Archives of Neurology and Psychiatry
Arch. Ophthal. = Archives of Ophthalmology
Arch. Path. = Archives of Pathology
Arch. Surg. = Archives of Surgery
Bull. N. Y. Acad. Med. = Bulletin of the New York Academy of Medicine
Ergebn. d. Physiol. = Ergebnisse der Physiologie biologischen Chemie und experimentellen Pharmakologie
J. A. M. A. = Journal of the American Medical Association
J. Anat. = Journal of Anatomy
J. Biol. Chem. = Journal of Biological Chemistry
J. Comp. Neurol. = Journal of Comparative Neurology
J. Com. Neurol. and Psychol. = Journal of Comparative Neurology and Psychology
J. Exp. Med. = Journal of Experimental Medicine
J. Lab. and Clin. Med. = Journal of Laboratory and Clinical Medicine
J. Nerv. and Ment. Dis. = Journal of Nervous and Mental Diseases
J. Neurophysiol. = Journal of Neurophysiology
J. Neurol. and Psychopath. = Journal of Neurology and Psychopathology
J. Pharmacol. and Exp. Therap. = Journal of Pharmacology and Experimental Therapeutics
Physiol. Rev. = Physiological Reviews
Proc. Inst. Med. Chicago = Proceedings of the Institute of Medicine of Chicago
Proc. Soc. Exp. Biol. and Med. = Proceedings of the Society for Experimental Biology and Medicine
Psychiat. en neurol. bl. = Psychiatrische en Neurologische Bladen
Psychosomat. Med. = Psychosomatic Medicine
Quart. Bull. Northwestern Univ. Med. School = Quarterly Bulletin, Northwestern University Medical School

Res. Publ. Assn. Nerv. Ment. Dis. = Research Publications of the Association for Research in Nervous and Mental Diseases
Rev. neurol. = Revue neurologique
Rev. Neurol. and Psychiat. = Review of Neurology and Psychiatry
Trans. Am. Neurol. Assn. = Transactions of the American Neurological Association
Trans. Chicago Path. Soc. = Transactions of the Chicago Pathological Society
Trans. Coll. Phys. of Phila. = Transactions of the College of Physicians of Philadelphia.

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(Note: References 213 and 214 were published in 1943 after the death of Professor Ranson.)